VOL. 1

Azadi Ka Amrit Mahotsav

Agriculture and Allied Sciences

Restructured and Revised Syllabi of Post-graduate Programmes

- Plant Sciences
- Forestry
- Plant Protection
- Sericulture
- Horticultural Sciences

भाकृअनुप
ICAR

Education Division
Indian Council of Agricultural Research
New Delhi

www.icar.gov.in

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Printed : December 2021

ISBN: 978-81-7164-235-9

Published by Dr Satendra Kumar Singh, Project Director, Directorate of Knowledge Management in Agriculture, Indian Council of Agricultural Research, KAB-I, Pusa, New Delhi 110 012; laser typeset by Xpedite Computer Systems, WZ-276 F1-B, Inderpuri, New Delhi 110 012 and printed at M/s Chandu Press, 469, Patparganj Industrial Estate, Delhi 110 092.

सत्यमेव जयते

त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

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Foreword

THE ICAR has been continuously striving to bring necessary reforms for quality assurance in agricultural education. The Council has appointed National Core Group and BSMA Committees for revision and restructuring of Post-graduate and Doctoral syllabi in consultation with all the stakeholders to meet the challenges and harness opportunities in various disciplines of agriculture and allied sciences. It has been observed that a paradigm shift is necessary in academic regulations to comply with various provisions of National Education Policy-2020. It is heartening to note that the respective Committees have taken due care by following flexible, multi-disciplinary and holistic approach while developing the syllabus and academic regulations. The students are given opportunities to select the courses to support their planned research activities, to register for online courses and to pursue internship for development of entrepreneurship during Masters' programme. Further, the Teaching Assistantship has been introduced to provide experience to the Ph.D. scholars on teaching, evaluation and other related academic matters. This is an important part of doctoral training all over the world and it is expected to address the shortage of faculty in many institutions/universities. By intensive discussion with the subject experts and based on the feedback from the faculty and students, the syllabus of Masters' and Doctoral programmes in 79 disciplines was restructured and new courses were introduced. The syllabus has been revised suitably with the view to equip the students to gain knowledge, enhance their employability and skill sets to mould towards entrepreneurship and build themselves to prepare for global competitiveness. The opinions and suggestions invited from the concerned institutions, eminent scientists and other stakeholders were also reviewed by the Committees.

The Council sincerely thanks Dr Arvind Kumar, Chairman of the National Core Group and its members for the guidance to develop the syllabus in line with contemporary and projected national and global agricultural trends. The Council acknowledges the dedicated efforts and contribution of all the Chairpersons and members of 19 BSMA Committees for preparation of the syllabus. It gives me immense pleasure to express profuse thanks to the Agricultural Education Division for accomplishing this mammoth task under the guidance of Dr N.S. Rathore, former DDG and Dr R.C. Agrawal, DDG. I compliment Dr G. Venkateshwarlu, former ADG (EQR) for his sincere efforts and overall coordination of the meetings. Special thanks to DKMA for bringing out the entire syllabus in six volumes.

(T. Mohapatra)

Date: 13th August 2021
Place: New Delhi-110 001

Preface

THE curricula development is a part of the continued process and effort of the ICAR in this direction for dynamic improvement of national agricultural education system. In this resolve, the ICAR has constituted a National Core Group (NCG) for restructuring of Master's and Ph.D. curriculum, syllabi and academic regulations for the disciplines under agricultural sciences. On the recommendations of the NCG, 19 Broad Subject Matter Area (BSMA) Committees have been constituted by the ICAR for revising the syllabus. These Committees held discussions at length in the meetings and workshops organized across the country. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the Committees. The respective BSMA Committees have examined the existing syllabus and analysed carefully in terms of content, relevance and pattern and then synthesized the new syllabus.

The revised curricula of 79 disciplines has been designed with a view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. To mitigate the concerns related to agriculture education system in India and to ensure uniform system of education, several changes have been incorporated in common academic regulations in relation to credit load requirement and its distribution, system of examination, internship during Masters programme, provision to enrol for online courses and take the advantage of e-resources through e-learning and teaching assistantship for Ph.D. scholars. As per recommendations of the National Education Policy-2020, the courses have been categorized as Major and Minor/Optional courses. By following the spirit of Choice Based Credit System (CBCS), the students are given opportunity to select courses from any discipline/department enabling the multi-disciplinary approach.

We place on record our profound gratitude to Dr Trilochan Mohapatra, Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG and Ph.D. programs in agriculture and allied sciences. The Committee is deeply indebted to Dr R.C. Agrawal, DDG (Agri. Edn), and to his predecessor Dr N.S. Rathore for their vision and continuous support. Our thanks are due to all Hon'ble Vice Chancellors of CAUs/SAUs/DUs for their unstinted support and to nominate the senior faculty from their universities/institutes to the workshops organized as a part of wider consultation process.

The revised syllabi encompass transformative changes by updating, augmenting, and revising course curricula and common academic regulations to achieve necessary quality and need-based agricultural education. Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and need both at national and international level. We earnestly hope that this document will meet the needs and motivate different stakeholders.

G. Venkateshwarlu
Member-Secretary

Arvind Kumar
Chairman, National Core Group

Overview

A National Core Group has been constituted by ICAR for development of Academic Regulations for Masters and Ph.D. programmes, defining names and curricula of Masters' and Ph.D. disciplines for uniformity and revision of syllabi for courses of Masters' and Ph.D. degree disciplines. On the recommendations of the members of National Core Group, 19 Broad Subject Matter Area (BSMA) Committees have been constituted for revising the syllabus. These committees have conducted several meetings with the concerned experts and stakeholders and developed the syllabus for their respective subjects. While developing the syllabi, various provisions of National Education Policy-2020 have also been considered and complied to provide quality higher education and develop good, thoughtful, well-rounded, and creative individuals. Necessary provisions have been made in the curricula to enable an individual to study major and minor specialized areas of interest at a deep level, and also develop intellectual curiosity, scientific temper and creativity.

I express my gratefulness to Dr Arvind Kumar, Vice-Chancellor, Rani Lakshmi Bai Central Agricultural University, Jhansi and Chairman, National Core Group under whose guidance the syllabi for Master's and Doctoral programme is completed. His vast experience in agricultural education and research helped in finalising the syllabi. I wish to place on record the suggestions and directions shown by Dr N.S. Rathore, former Deputy Director General (Education) and Dr G. Venkateswarlu, ADG (EQR) and Member Secretary, National Core Group throughout the period without which the present target could not have been achieved. I am extremely thankful to 19 BSMA Committees for their stupendous job in restructuring and articulating curricula in the light of technological developments and employability prospects in agriculture and allied sciences. I also appreciate and acknowledge the efforts made by Dr S.K. Sankhyan, Principal Scientist (EQR), Dr S.K. Singh, Project Director (DKMA), Mr Punit Bhasin, Incharge, Production Unit (DKMA), Dr Kshitij Malhotra and Dr Sumit Saini, Research Associates to take up the work of editing, proof reading, finalizing and bringing out these six volumes of BSMA in this shape.

I also take this opportunity to express a deep sense of gratitude to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his guidance, cordial support and valuable input throughout the revision of the syllabus by BSMA, which helped in completing this task through various stages. The support and help extended by all Deputy Director Generals and the staff of Education Division is also greatly acknowledged.

During this comprehensive exercise of upgrading the course contents, the much-needed academic support, hospitality and participation rendered by Hon'ble Vice-Chancellors of CAUs/SAUs/DUs is greatly acknowledged. My deep sense of gratitude goes to Deans, Directors, Professors, Heads, faculty members and students at the universities who contributed by their effective participation and interaction.

R.C. Agrawal

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1. Academic Year and Registration

- An academic year shall be normally from July to June of the following calendar year otherwise required under special situations. It shall be divided into two academic terms known as semesters. Dates of registration, commencement of instructions, semester end examination, end of semester and academic year, etc. The Academic Calendar shall be developed by the concerned University from time to time and notified accordingly by the Registrar in advance.
- An orientation programme shall be organized by the Director (Education)/ Dean PGS for the benefit of the newly admitted students immediately after commencement of the semester.
- On successful completion of a semester, the continuing students shall register for subsequent semester on the date specified in the Academic/ Semester Calendar or specifically notified separately. Every enrolled student shall be required to register at the beginning of each semester till the completion of his/ her degree programmes.

2. Credit requirements

2.1 Framework of the courses

The following nomenclature and Credit Hrs need to be followed while providing the syllabus for all the disciplines:

		Masters' Programme	Doctoral Programme
(i)	**Course work**		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
	Seminar	01	02
(ii)	**Thesis Research**	30	75
	Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken may be given *mark

Minor courses: From the subjects closely related to a student's major subject

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/ her overallcompetence.

Common Courses: The following courses (one credit each) will be offered to all students undergoing Master's degree programme:

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the Head of Department (HoD)/ Board of Studies (BoS).

2.2 Supporting Courses

The following courses are being offered by various disciplines (The list is only indicative). Based on the requirement, any of the following courses may be opted under the supporting courses. The syllabi of these courses are available in the respective disciplines. If required, the contents may be modified to suit the individual discipline with approval of the concerned BoS:

Code	Course Title	Credit Hours
STAT 501	Mathematics for Applied Sciences	2+0
STAT 502	Statistical Methods for Applied Sciences	3+1

Course Code	Course Title	Credit Hours
STAT 511	Experimental Designs	2+1
STAT 512	Basic Sampling Techniques	2+1
STAT 521	Applied Regression Analysis	2+1
STAT 522	Data Analysis Using Statistical Packages	2+1
MCA 501	Computers Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Communication Technologies, Computer Networking and Internet	1+1
MCA 512	Information Technology in Agriculture	1+1
BIOCHEM 501	Basic Biochemistry	3+1
BIOCHEM 505	Techniques in Biochemistry	2+2

2.3 Syllabus of Common Courses for PG programmes

LIBRARY AND INFORMATION SERVICES (0+1)

Objective

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

To equip the students/ scholars with skills to write dissertations, research papers, etc. To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical (Technical Writing)

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.;
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion);
- Writing of abstracts, summaries, précis, citations, etc.;

- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups;
- Editing and proof-reading;
- Writing of a review article;
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors), Concord, Collocation, Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech;
- Participation in group discussion;
- Facing an interview;
- Presentation of scientific papers.

Suggested Readings

1. Barnes and Noble. Robert C. (Ed.). 2005. *Spoken English: Flourish Your Language.*
2. *Chicago Manual of Style*. 14th Ed. 1996. Prentice Hall of India.
3. *Collins' Cobuild English Dictionary*. 1995.
4. Harper Collins. Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed.
5. Holt, Rinehart and Winston. Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed. Oxford University Press.
6. James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
7. Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
8. Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
9. Richard WS. 1969. *Technical Writing.*
10. Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
11. Wren PC and Martin H. 2006. *High School English Grammar and Composition.* S. Chand & Co.

INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE (1+0)

Objective

The main objective of this course is to equip students and stakeholders with knowledge of Intellectual Property Rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National

Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Readings

1. Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
2. Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
3. *Intellectual Property Rights: Key to New Wealth Generation*. 2001. NRDC and Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
5. Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
6. Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; The Biological Diversity Act, 2002.

BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab;
- Handling of chemical substances;
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;
- Washing, drying and sterilization of glassware;
- Drying of solvents/ chemicals;
- Weighing and preparation of solutions of different strengths and their dilution;
- Handling techniques of solutions;
- Preparation of different agro-chemical doses in field and pot applications;
- Preparation of solutions of acids;
- Neutralisation of acid and bases;
- Preparation of buffers of different strengths and pH values;
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath;
- Electric wiring and earthing;
- Preparation of media and methods of sterilization;
- Seed viability testing, testing of pollen viability;
- Tissue culture of crop plants;
- Description of flowering plants in botanical terms in relation to taxonomy.

Suggested Readings

1. Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press.

2. Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (1+0)

Objective

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

Suggested Readings

1. Bhalla GS and Singh G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Publ.
2. Punia MS. *Manual on International Research and Research Ethics.* CCS Haryana Agricultural University, Hisar.
3. Rao BSV. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Publ.
4. Singh K. 1998. *Rural Development - Principles, Policies and Management*. Sage Publ.

2.4 Mandatory requirement of seminars

- It has been agreed to have mandatory seminars one in Masters (One Credit) and two in Doctoral programmes (two Credits).
- The students should be encouraged to make presentations on the latestdevelopments and literature in the area of research topic. This will provide training to the students on preparation for seminar, organizing the work, critical analysis of data and presentation skills.

3. Residential requirements

- The minimum and maximum duration of residential requirement for Masters'

Degree and Ph.D. Programmes shall be as follows:

P.G. Degree Programmes	Duration of Residential Requirement	
	Minimum	Maximum
Masters' Degree	2 Academic Years (4 Semesters)	5 Academic Years (10 Semesters)
Ph.D.*	3 Academic Years (6 Semesters)	7 Academic Years (14 Semesters)

*Student may be allowed to discontinue temporarily only after completion of course work

In case a student fails to complete the degree programme within the maximum duration of residential requirement, his/ her admission shall stand cancelled. The requirement shall be treated as satisfactory in the cases in which a student submits his/ her thesis any time during the 4^{th} and 6^{th} semester of his/ her residentship at the University for Masters' and Ph.D. programme, respectively.

4. Evaluation of course work and comprehensive examination

- For M.Sc., multiple levels of evaluation (First Test, Midterm and Final semester) is desirable. However, it has been felt that the comprehensive examination is redundant for M.Sc. students.
- For Ph.D., the approach should be research oriented rather than exam oriented. In order to provide the student adequate time to concentrate on the research work and complete the degree in stipulated time, the examination may have to be only semester final. However, the course teacher may be given freedom to evaluate in terms of assignment/ seminar/ first test.
- For Ph.D., the comprehensive examination (Pre-qualifying examination) is required. As the students are already tested in course examinations, the comprehensive examinationshould be based onoral examinationby an external expert and the evaluation should cover both the research problem and theoretical background to execute the project. This shall assess the aptitude of the student and suitability of the student for the given research topic. The successful completion of comprehensive examination is to obtain the "Satisfactory" remark by the external expert.

5. Advisory System

5.1 Advisory Committee

- There shall be an Advisory Committee for every student consisting of not fewer than three members in the case of a candidate for Masters' degree and four in the case of Ph.D. degree with the Advisor as Chairperson. The Advisory Committee should have representatives from the major and minor fields amongst the members of the Post-graduate faculty accredited for appropriate P.G. level research. However, in those departments where qualified staff exists but due to unavoidable reasons Post-graduate degree programmes are not existing, the staff having Post-graduate teaching experience of two years or more may be included in the Advisory Committee as member representing the minor.
- At any given time, a P.G. teacher shall not be a Chairperson, Advisory Committee (including Master's and Ph.D. programmes) for more than five students.

- The Advisor should convene a meeting of the Advisory Committee at least once in a Semester. The summary record should be communicated to the Head of Department, Dean of the College of concerned, Director (Education)/ Dean PGS and Registrar for information.

Advisor/ Co-guide/ Member, Advisory Committee from other collaborating University/ Institute/ Organization

- In order to promote quality Post-graduate research and training in cutting edge areas, the University may enter into Memorandum of Understanding (MOU) with other Universities/ Institutions for conducting research. While constituting an Advisory Committee of a student, if the Chairperson, Advisory Committee feels the requirement of involving of a faculty member/ scientist of such partnering university/ Institute/ Organization, he/ she may send a proposal to this effect to Director (Education)/ Dean PGS along with the proposal for consideration of Student's Advisory Committee (SAC).
- The proposed faculty member from the partnering institution can be allowed to act as Chairperson/ Co-guide/ Member, SAC, by mutual consent, primarily on the basis of intellectual input and time devoted for carrying out the research work at the particular institution. The faculty member/ scientist of partnering institutions in the SAC shall become a temporary faculty member of the University by following the procedure approved by the Academic Council.

Allotment of students to the retiring persons

Normally, retiring person may not be allotted M. Sc. Student if he/ she is left with less than 2 years of service and Ph.D. student if left with less than 3 years of service. However, in special circumstances, permission may be obtained from the Director (Education)/ Dean PGS, after due recommendation by the concerned Head of the Department.

Changes in the Advisory Committee:

(i) Change of the Chairperson or any member of the Advisory Committee is not ordinarily permissible. However, in exceptional cases, the change may be effected with due approval of the Director of Education/ Dean PGS.

(ii) Normally, staff members of the university on extra ordinary leave or on study leave or who leave the University service will cease to continue to serve as advisors of the Post-graduate students of the University. However, the Director (Education)/ Dean PGS may permit them to continue to serve as advisor subject to the following conditions:

- (a) The concerned staff member must be resident in India and if he/ she agrees to guide research and must be available for occasional consultations;
- (b) An application is made by the student concerned duly supported by the Advisory Committee;
- (c) In case of a Ph.D. student, he/ she must have completed his/ her comprehensive examinations and the research work must be well in progress and it is expected that the student will submit the thesis within a year;
- (d) The Head of the Department and the Dean of the College concerned agree to the proposal;

(e) The staff member, after leaving the University service is granted the status of honorary faculty's membership by the Vice-Chancellor on the recommendation of the Director (Education)/ Dean PGS for guiding as Chairperson or Member, Advisory Committee the thesis/ theses of the student(s) concerned only.

(iii) In case the Chairperson/ member of a Student's Advisory Committee retires, he/ she shall be allowed to continue provided that the student has completed his course work and minimum of 10 research credits and the retiring Chairperson/ member stays at the Headquarters of the College, till the thesis is submitted.

(iv) If the Chairperson/ member proceeds on deputation to another organization, he/ she may be permitted to guide the student provided his/ her new organization is at the Headquarters of the College and his/ her organization is willing for the same.

(v) The change shall be communicated to all concerned by the Head of Department.

6. Evaluation of research work

- It is highly desirablefor Ph.D. programme and this should be done annually as an essential part of research evaluation. The Student Advisory Committee shallreview the progress of research and scrutinize annual progress reports submitted by the student.
- Midterm evaluation of Ph.D. (to move from JRF to SRF) is a mandatory requirement for all the funding agencies. Hence, the second review of annual progress report need to be done after completion of two years. The successful completion enables the students to become eligible for SRF.

6.1 Prevention of plagiarism

- An institutional mechanism should be in place to check the plagiarism. The students must be made aware that manipulation of the data/ plagiarism is punishable with serious consequences.

7. Learning through online courses

- In line with the suggestion in new education policy and the initiatives taken by ICAR and MHRD in the form of e-courses, MOOCs, SWAYAM, etc. and also changes taking place globally in respect of learning through online resources it has been agreed to permit the students to enrol for online courses. It is expected that the provision of integrating available online courses with the traditional system of education would provide the students opportunities to improve their employability by imbibing the additional skills and competitive edge.

The Committee recommends the following points while integrating the online courses:

1. Board of Studies (BoS) of each Faculty shall identify available online courses and a student may select from the listed courses. The interested students may provide the details of the on-line courses to the BoS for its consideration.
2. A Postgraduate student may take up to a maximum of 20% credits in a semester through online learning resources.
3. The host institute offering the course does the evaluation and provide marks/ grades. The BoS shall develop the conversion formula for calculation of GPA and it may do appropriate checks on delivery methods and do additional evaluations, if needed.

8. Internship during Masters programme

Internship for Development of Entrepreneurship in Agriculture (IDEA)

Currently, a provision of 30 credits for dissertation work in M.Sc./ M.Tech/ M.F.Sc./ M.V.Sc. programmes helps practically only those students who aspire to pursue their career in academic/ research. There is hardly any opportunity/ provision under this system to enhance the entrepreneurship skills of those students who could start their own enterprise or have adequate skills to join the industry. Therefore, in order to overcome this gap, an optional internship/ in-plant training (called as IDEA) in lieu of thesis/ research work is recommended which will give the students an opportunity to have a real-time hands-on experience in the industry.

It is envisaged that the internship/ in-plant training would enhance the interactions between academic organizations and the relevant industry. It would not only enable the development of highly learned and skilled manpower to start their-own enterprises but also the industry would also be benefitted through this process. This pragmatic approach would definitely result in enhancedpartnerships between academia and industry.

The main objectives of the programme:

1. To promote the linkages between academia and industry
2. To establish newer University – Cooperative R&D together with industry for knowledge creation, research and commercialization
3. Collaboration between Universities and industries through pilot projects
4. To develop methods for knowledge transfer, innovation and networking potential
5. To enhance skill, career development and employability

Following criteria for IDEA will be taken into consideration:

- At any point of time there will not be more than 50% of students who can opt under IDEA
- Major Advisor will be from Academia and Co-advisor (or Advisory Committee member) from industry
- Total credits (30) will be divided into 20 for internship/ in-plant training and10 for writing the report followed by viva-voce similar to dissertation
- Work place will be industry; however, academic/ research support would be provided by the University or both. MoU may be developed accordingly
- The IPR, if any, would be as per the University policy

9. Teaching assistantship

- Teaching assistantship shall be encouraged. This will give the required experience to the students on how to conduct courses, practical classes, evaluation and other related academic matters. This is an important part of Ph.D. training all over the world and it is expected to address the shortage of faculty in many institutions/ universities.
- The fulltime doctoral students of the University with or without fellowship may be considered for award of Teaching Assistantships in their respective Departments. The Teaching Assistantship shall be offered only to those doctoral students who have successfully finished their course work. Any consideration for award of Teaching Assistantships must have the consent ofthe supervisor concerned.
- Teaching Assistantships shall be awarded on semester to semester basis on the recommendation of a screening/ selection committee to be constituted by the

ViceChancellor. All classes and assignments given to the Teaching Assistants, including tutorials, practicals and evaluation work shall be under the supervision of a faculty member who would have otherwise handled the course/ assignment.

- Each Ph.D. student may be allowed to take a maximum of 16 classes in a month to UG/ Masters students.
- No additional remuneration shall be paid to the students who are awarded ICAR JRF/ SRF. The amount of fellowship to be paid as remuneration to other students (who are receiving any other fellowship or without any fellowships) may be decided by the concerned universities as per the rules in force.However, the total amount of remuneration/ and fellowship shall not exceed the amount being paid as JRF/ SRF of ICAR.
- At the end of each term, Teaching Assistants shall be given a certificate by the concerned Head of the Department, countersigned by the School Dean, specifying the nature and load of assignments completed.

10. Registration of project personnel (SRF/ RA) for Ph.D.

- A provision may be made to enable the project personnel (SRF/ RA) to register for Ph.D. However, this can be done only if they are selected based on some selection process such as walk-in-interview. The prior approval of PI of the project is mandatory to consider the application of project personnel (SRF/ RA) for Ph.D. admission
- The candidates need to submit the declaration stating that the project work shall not be compromised because of Ph.D. programme. Further, in order to justify the project work and Ph.D. programme, the number of course credits should not be more than 8 in a semester for the project personnel (SRF/ RA) who intend to register for Ph.D.

11. Compliance with the National Education Policy-2020

- While implementing the course structure and contents recommended by the BSMA Committees, the Higher Education Institutions (HEIs) are required to comply with the provisions of National Education Policy-2020, especially the following aspects:
- Given the 21st century requirements, quality higher education must aim to develop good, thoughtful, well-rounded, and creative individuals. It must enable an individual to study one or more specialized areas of interest at a deep level, and also develop character, ethical and Constitutional values, intellectual curiosity, scientific temper, creativity, spirit of service, and 21st century capabilities across a range of disciplines including sciences, social sciences, arts, humanities, languages, as well as professional, technical, and vocational subjects. A quality higher education must enable personal accomplishment and enlightenment, constructive public engagement, and productive contribution to the society. It must prepare students for more meaningful and satisfying lives and work roles and enable economic independence (9.1.1. of NEP-2020).
- At the societal level, higher education must enable the development of an enlightened, socially conscious, knowledgeable, and skilled nation that can find and implement robust solutions to its own problems. Higher education must form the basis for knowledge creation and innovation thereby contributing to a growing national economy. The purpose of quality higher education is, therefore, more than the creation of greater opportunities for individual employment. It represents the key to more vibrant, socially engaged, cooperative communities and a happier,

cohesive, cultured, productive, innovative, progressive, and prosperous nation (9.1.3. of NEP-2020).

- Flexibility in curriculum and novel and engaging course options will be on offer to students, in addition to rigorous specialization in a subject or subjects. This will be encouraged by increased faculty and institutional autonomy in setting curricula. Pedagogy will have an increased emphasis on communication, discussion, debate, research, and opportunities for cross-disciplinary and interdisciplinary thinking (11.6 of NEP-2020).
- As part of a holistic education, students at all HEIs will be provided with opportunities for internships with local industry, businesses, artists, crafts persons, etc., as well as research internships with faculty and researchers at their own or other HEIs/ research institutions, so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability (11.8 of NEP-2020).
- HEIs will focus on research and innovation by setting up start-up incubation centres; technology development centres; centres in frontier areas of research; greater industry-academic linkages; and interdisciplinary research including humanities and social sciences research (11.12. of NEP-2020).
- Effective learning requires a comprehensive approach that involves appropriate curriculum, engaging pedagogy, continuous formative assessment, and adequate student support. The curriculum must be interesting and relevant, and updated regularly to align with the latest knowledge requirements and to meet specified learning outcomes. High-quality pedagogy is then necessary to successfully impart the curricular material to students; pedagogical practices determine the learning experiences that are provided to students, thus directly influencing learning outcomes. The assessment methods must be scientific, designed to continuously improve learning and test the application of knowledge. Last but not least, the development of capacities that promote student wellness such as fitness, good health, psycho-social well-being, and sound ethical grounding are also critical for high-quality learning (12.1. of NEP-2020).

Definitions of Academic Terms

Chairperson means a teacher of the major discipline proposed by the Head of Department through the Dean of the College and duly approved by the Director of Education/ Dean Post Graduate Studies (or as per the procedure laid down in the concerned University regulations) to act as the Chairperson of the Advisory Committee and also to guide the student on academic issues.

Course means a unit of instruction in a discipline carrying a specific number and credits to be covered in a semester as laid down in detail in the syllabus of a degree programme.

Credit means the unit of work load per week for a particular course in theory and/ or practical. One credit of theory means one class of one clock hour duration and one credit practical means one class of minimum two clock hoursof laboratory work per week.

Credit load of a student refers to the total number of credits of all the courses he/ she registers during a particular semester.

Grade Point (GP) of a course is a measure of performance. It is obtained by dividing the per cent mark secured by a student in a particular course by 10, expressed and rounded off to second decimal place.

Credit Point (CP) refers to the Grade point multiplied by the number of credits of the course, expressed and rounded off to second decimal place.

Grade Point Average (GPA) means the total credit point earned by a student divided by total number of credits of all the courses registered in a semester, expressed and rounded off to second decimal place.

Cumulative Grade Point Average (CGPA) means the total credit points earned by a student divided by the total number of credits registered by the student until the end of a semester (all completed semesters), expressed and rounded off to second decimal place.

Overall Grade Point Average (OGPA) means the total credit points earned by a student in the entire degree programme divided by the total number of credits required for the P.G. degree, expressed and rounded off to second decimal place.

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 1

Plant Sciences

– Genetics and Plant Breeding
– Seed Sciences and Technology
– Plant Genetic Resources

Contents

Acknowledgements

The Committee is indebted to Indian Council of Agricultural Research, New Delhi for assigning the responsibility of restructuring the course curriculum of Plant Sciences in the light of scientific developments taking place globally.

I express my gratefulness to Prof. Arvind Kumar, Vice-Chancellor, RLBCAU, Jhansi and Chairman, National Core Committee under whose visionary guidance the syllabi for Master's and Doctoral programme is completed. His vast knowledge, experience and contribution in agricultural education and research helped in finalising the syllabi of Plant Sciences.

This BSMA committee wishes to place on record the encouragement, suggestions and directions shown by Dr N.S. Rathore, former DDG (Education); Dr R.C. Agrawal, DDG (Education); Dr G. Venkateswarlu, ADG (EQR) and Member Secretary and Dr K.L. Khurana, Principal Scientist, Education Division of ICAR, New Delhi throughout the entire period without which the present target could not have been achieved.

The much needed academic support, hospitality and participation rendered for upgrading the course contents by Vice-Chancellors of Bhubaneswar, Prof. S.N. Pasupalak; TNAU, Coimbatore, Prof. K. Ramasamy; SKUAST, Jammu Prof. Pradeep Kumar Sharma; SKNAU, Jobner, Prof. P.S. Rathore is greatly acknowledged. My deep gratitude to Deans, Directors, Professors, Heads, faculty members and students of these universities for effective participation and interaction.

I am extremely grateful to BSMA Plant Science committee members, viz., Prof. B. Baisakh, Dean, PGF-cum-DRI and Convener OUAT, Bhubaneswar; Prof. S.R. Maloo, Former Dean/ Director Research, MPUAT, Udaipur; Prof. Jag Paul Sharma, Director Research, SKUAST, Jammu; Prof. S. Sundareswaran, Director Seeds, TNAU, Coimbatore and Prof. Rekha Chaudhury, NBPGR, New Delhi for restructuring and articulating curricula of plant science meticulously in the light of innovations, technological developments and employability.

The guidance and support of invited senior members, viz., Dr R.K. Sharma, Head, Dr R.S. Raje, Principal Scientist, Division of Genetics, IARI, New Delhi; Dr D.K. Yadava, Head, Division of Seed Science and Technology, IARI and Assistant Director General (Seeds), ICAR, New Delhi; Prof. V.K. Sood, Principal Scientist, CSK HPKV, Palampur; Dr S.K. Malik, Principal Scientist, ICAR HQ, New Delhi and Dr Dhirendra Singh, Professor and Head, SKN College of Agriculture, Jobner is duly acknowledged.

Z.S. Solanki
Chairman
and
Former V.C., Agril. Uni., Kota.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Sciences
– Genetics and Plant Breeding

Preamble

(Genetics and Plant Breeding)

Plant improvement has a long history for its growth and development. Plant breeding became established as a science in the twentieth century following the rediscovery of Mendel's laws of inheritance. Nearly 50% of global increase in food production is attributed to plant breeding. Since genetic improvement in an inherent feature, products of plant breeding can have wide global impact as exemplified by the Green Revolution for wheat and rice varieties of 1960s or transgenic crops of recent decades. Therefore developing sufficient human resources in Genetics and Plant Breeding with advanced knowledge and technical skill will further elevate the agricultural sector to attain a new peak in increasing food production matching the requirement of population.

Present agriculture research and international market demand the need for specialised human resource for teaching cutting edge technology with application of biotechnology, nanotechnology, artificial intelligence in crop improvement, increasing entrepreneurship, etc., would warrant students to have strong knowledge of practical and management skills which will help them to face the competitiveness in public and private sector.

Hence, restructuring of course curricula and delivery system to match with the present situation is the need of the time. In this proposed revision of curriculum in Genetics and Plant Breeding, the BSMA sub-group organized a series of meetings and electronic media-led consultations to develop a set of courses suitable for M. Sc. and Ph. D. students of the discipline.

The meetings were focussed on the basic principles as well as the innovative developments in Genetics and Plant Breeding, as the platform building status of Plant Sciences. Built on this platform with the latest state of the art technologies including biotechnology and molecular biology will enable a complete coverage of the subjects. The basic courses have therefore been kept as compulsory courses which need to be taken by all the students irrespective of the subject specialization or stream from which they entered into PG education.

The BSMA Committee had thread bare discussions over four sessions on the topical issues concerning Genetics and Plant Breeding, Seed Science and Technology and Plant Genetic Resources. The curricula and syllabi of all these disciplines were discussed at length in the meetings and workshops. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the committee. The new look and restructured PG programmes in Genetics and Plant Breeding have been designed in considerations based on demands of private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and to enhance the global competitiveness and employability of our students. Considerable efforts have, therefore gone in for the preparation of this document.

Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and social need both at national and international level are Molecular Breeding and Bioinformatics, Breeding for Quality and Special Traits, Seed Production and Certification, Breeding Vegetable Crops, Breeding Fruit Crops, Breeding Ornamental Crops for M.Sc. and IPR and Regulatory Mechanism (e-course) as well as Population Genetics for Ph.D. programme.

Course Title with Credit Load
M.Sc. (Ag) in Genetics and Plant Breeding (GPB)

Course Code	Course Title	Credit Hours
GPB 501*	Principles of Genetics	3 (2+1)
GPB 502*	Principles of Plant Breeding	3 (2+1)
GPB 503*	Fundamentals of Quantitative Genetics	3 (2+1)
GPB 504	Varietal Development and Maintenance Breeding	2 (1+1)
GPB 505	Principles of Cytogenetics	3 (2+1)
GPB 506*	Molecular Breeding and Bioinformatics	3 (2+1)
GPB 507	Breeding for Quality and Special Traits	3 (2+1)
GPB 508	Mutagenesis and Mutation Breeding	3 (2+1)
GPB 509	Hybrid Breeding	3 (2+1)
GPB 510	Seed Production and Certification	2 (1+1)
GPB 511	Crop Breeding-I *(Kharif* Crops)	3 (2+1)
GPB 512	Crop Breeding-II *(Rabi* Crops)	3 (2+1)
GPB 513	Breeding Vegetable Crops	3 (2+1)
GPB 514	Breeding Fruit Crops	3 (2+1)
GPB 515	Breeding Ornamental Crops	3 (2+1)
GPB 516	Breeding for Stress Resistance and Climate Change	3 (2+1)
GPB 517	Germplasm Characterization and Evaluation	2 (1+1)
GPB 518	Genetic enhancement for PGR Utilization	2 (1+1)
	Major courses (minimum 20 credits from above courses including *marked Courses)	**20**
	Minor courses	08
	Supporting courses	06
	Common compulsory courses	05
GPB 591	Seminar	01
GPB 599	Thesis/ Research	30
	Total Credits	70

*Compulsory Major Courses

Course Contents
M.Sc. (Ag) in Genetics and Plant Breeding (GPB)

I. Course Title : Principles of Genetics*

II. Course Code : GPB 501

III. Credit Hours : 3 (2+1)

IV. Why this course?

Genes are the backbone of all crop improvement activities. Their chemical structure and physical inheritance are pivotal for any breeding program. Therefore, it has to be the core course for master's degree in Genetics and Plant Breeding.

V. Aim of the course

This course is aimed at understanding the basic concepts of inheritance of genetic traits, helping students to develop their analytical, quantitative and problem-solving skills from classical to molecular genetics.

VI. Theory

Unit I

Beginning of genetics, early concepts of inheritance, Mendel's laws; Discussion on Mendel's paper, Chromosomal theory of inheritance; Multiple alleles, Gene interactions, Sex determination, differentiation and sex-linkage, Sex-influenced and sex-limited traits; Linkage-detection, estimation; Recombination and genetic mapping in eukaryotes, Somatic cell genetics, Extra chromosomal inheritance.

Unit II

Mendelian population, Random mating population, Frequencies of genes and genotypes, Causes of change: Hardy-Weinberg equilibrium.

Unit III

Nature, structure and replication of the genetic material; Organization of DNA in chromosomes, Genetic code; Protein biosynthesis, Genetic fine structure analysis, Allelic complementation, Split genes, overlapping genes, Pseudogenes, Oncogenes, Gene families and clusters; Regulation of gene activity in prokaryotes and eukaryotes; Molecular mechanisms of mutation, repair and suppression; Bacterial plasmids, insertion (IS) and transposable (Tn) elements; Molecular chaperones and gene expression, RNA editing.

Unit IV

Gene isolation, synthesis and cloning, genomic and cDNA libraries, PCR based cloning, positional cloning; Nucleic acid hybridization and immunochemical detection; DNA sequencing; DNA restriction and modification, Anti-sense RNA and ribozymes; Micro-RNAs (miRNAs).

Unit V

Genomics and proteomics; metagenomics; Transgenic bacteria and bioethics; Gene silencing; genetics of mitochondria and chloroplasts. Concepts of Eugenics, Epigenetics, Genetic disorders.

VII. Practical

- Laboratory exercises in probability and chi-square;
- Demonstration of genetic principles using laboratory organisms;
- Chromosome mapping using three-point test cross;
- Tetrad analysis; Induction and detection of mutations through genetic tests;
- DNA extraction and PCR amplification;
- Electrophoresis: basic principles and running of amplified DNA;
- Extraction of proteins and isozymes;
- Use of *Agrobacterium* mediated method and Biolistic gun;
- Detection of transgenes in the exposed plant material;
- Visit to transgenic glasshouse and learning the practical considerations.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After passing out this course the student will be able to know the difference between the genotype and phenotype, can carry study on inheritance and also know the role of DNA and RNA in genotypic manifestation of characters.

X. Suggested reading

Daniel LH and Maryellen R. 2011. *Genetics: "Analysis of Genes and Genomes*".
Gardner EJ and Snustad DP. 1991. *Principles of Genetics*. John Wiley and Sons. 8th ed. 2006
Klug WS and Cummings MR. 2003. *Concepts of Genetics*. Peterson Edu. Pearson Education India; Tenth edition
Lewin B. 2008. *Genes XII*. Jones and Bartlett Publ. (International Edition) Paperback, 2018
Russell PJ. 1998. *Genetics*. The Benzamin/ Cummings Publ. Co
Singh BD. 2009. *Genetics*. Kalyani Publishers (2nd Revised Edition)
Snustad DP and Simmons MJ. 2006. *Genetics*. 4th Ed. John Wiley and Sons. 6th Edition International Student Version edition
Stansfield WD.1991. *Genetics*.Schaum Outline Series Mc Graw Hill
Strickberger MW. 2005. *Genetics* (*III Ed*). Prentice Hall, New Delhi, India; 3rd ed., 2015
Tamarin RH. 1999. *Principles of Genetics*. Wm. C. Brown Publs., McGraw Hill Education; 7 edition
Uppal S, Yadav R, Singh S and Saharan RP. 2005. *Practical Manual on Basic and Applied Genetics*. Dept. of Genetics, CCS HAU Hisar.

I. Course Title : Principles of Plant Breeding*

II. Course Code : GPB 502

III. Credit Hours : 3(2+1)

IV. Why this course?

Development of plant variety is the ultimate aim of any plant breeding program. A post graduate in the subject of agriculture must know what are the different selection methods, techniques and related crop improvement strategies. Further, knowledge of genetic resources, evolution and their role in development of noble varieties is the need of the hour.

V. Aim of the course

To impart theoretical knowledge and practical skills about plant breeding objectives, genetic consequences, breeding methods for crop improvement.

VI. Theory

Unit I

Early Plant Breeding; Accomplishments through plant breeding; Objectives of plant breeding; Patterns of Evolution in Crop Plants: Centre of Origin, Agro-biodiversity and its significance. Pre-breeding and plant introduction and role of plant genetic resources in plant breeding.

Unit II

Genetic basis of breeding: self and cross pollinated crops including mating systems and response to selection; Nature of variability, components of variation; Heritability and genetic advance, genotype environment interaction; General and specific combining ability; Types of gene actions and implications in plant breeding.

Unit III

Pure line theory, pure line and mass selection methods; pedigree, bulk, backcross, single seed descent and multiline breeding; Population breeding in self-pollinated crops with special reference to diallel selective mating; Transgressive breeding.

Unit IV

Breeding methods in cross pollinated crops; Population breeding: mass selection and ear-to-row methods; S_1 and S_2 progeny testing, progeny selection schemes, recurrent selection schemes for intra and inter-population improvement and development of synthetics and composites. Hybrid breeding: genetical and physiological basis of heterosis and inbreeding, production of inbreeds, breeding approaches for improvement of inbreeds, predicting hybrid performance; seed production of hybrid and their parent varieties/ inbreeds. Self-incompatibility, male sterility and apomixes in crop plants and their commercial exploitation.

Unit V

Breeding methods in asexually/ clonally propagated crops, clonal selection.

Unit VI

Special breeding techniques: Mutation breeding, Breeding for abiotic and biotic stresses; Concept of plant ideotype and its role in crop improvement, concept of MAS, concept of polyploidy and wide hybridization, doubled haploidy.

Unit VII

Cultivar development: testing, release and notification, maintenance breeding, Participatory Plant Breeding, Plant breeders' rights and regulations for plant variety protection and farmers rights.

VII. Practical

- Floral biology in self and cross pollinated species;
- Selfing and crossing techniques;
- Selection methods in segregating populations and evaluation of breeding material;
- Analysis of variance (ANOVA);
- Estimation of heritability and genetic advance;
- Maintenance of experimental records;

- Learning techniques in hybrid seed production using male-sterility in field crops;
- Prediction of performance of double cross hybrid.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

The knowledge of this course will enable the student to know breeding methods, different hybridization techniques for genomic reshuffling. The course will also acquaint the student with importance of floral biology, mutation breeding and participatory plant breeding, etc.

X. Suggested Reading

Allard RW. 1981. *Principles of Plant Breeding*. John Wiley & Sons.
Chahal GS and Gossal, SS. 2002. *Principles and Procedures of Plant Breeding Biotechnological and Conventional approaches*. Narosa Publishing House.
Chopra VL. 2004. *Plant Breeding*. Oxford & IBH.
George A. 2012. *Principles of Plant Genetics and Breeding*. John Wiley & Sons.
Gupta SK. 2005. *Practical Plant Breeding*. Agribios.
Jain HK and Kharakwal MC. 2004. *Plant Breeding and–Mendelian to Molecular Approach*, Narosa Publications, New Delhi
Roy D. 2003. *Plant Breeding, Analysis and Exploitation of Variation*. Narosa Publ. House.
Sharma JR. 2001. *Principles and Practice of Plant Breeding*. Tata McGraw-Hill.
Sharma JP. 2010. Principles of Vegetable Breeding. Kalyani Publ, New Delhi.
Simmonds NW.1990. *Principles of Crop Improvement*. English Language Book Society.
Singh BD. 2006. *Plant Breeding*. Kalyani Publishers, New Delhi.
Singh S and Pawar IS. 2006. *Genetic Bases and Methods of Plant Breeding*. CBS.

I. Course Title : Fundamentals of Quantitative Genetics*
II. Course Code : GPB 503
III. Credit Hours : 3 (2+1)

IV. Why this course?

Yield and quality characters are controlled by many genes and show the quantitative inheritance. If one has to go for improvement even for the components characters the knowledge of this course is very essential.

V. Aim of the course

To impart theoretical knowledge and computation skills regarding components of variation and variances, scales, mating designs and gene effects.

VI. Theory

Unit I

Introduction and historical background of quantitative genetics, Multiple factor hypothesis, Qualitative and quantitative characters, Analysis of continuous variation mean, range, SD, CV; Components of variation- Phenotypic, Genotypic, Nature of gene action- additive, dominance and epistatic, linkage effect. Principles of analysis of variance and linear model, Expected variance components, Random and fixed effect model, Comparison of means and variances for significance.

Unit II

Designs for plant breeding experiments- principles and applications; Variability parameters, concept of selection, simultaneous selection modes and selection of parents, MANOVA.

Unit III

Association analysis- Genotypic and phenotypic correlation, Path analysis Discriminate function and principal component analysis, Genetic divergence analysis- Metroglyph and D^2, Generation mean analysis, Parent progeny regression analysis

Unit IV

Mating designs- classification, Diallel, partial diallel, L × T, NCDs, and TTC; Concept of combining ability and gene action, G × E interaction-Adaptability and stability; Methods and models for stability analysis; Basic models- principles and interpretation, Bi-plot analysis.

Unit V

QTL mapping, Strategies for QTL mapping- Desired population and statistical methods, QTL mapping in genetic analysis; Markers, Marker assisted selection and factors influencing the MAS, Simultaneous selection based on marker and phenotype.

VII. Practical

- Analysis and interpretation of variability parameters;
- Analysis and interpretation of Index score and Metroglyph;
- Clustering and interpretation of D^2 analysis;
- Genotypic and phenotypic correlation analysis and interpretation;
- Path coefficient analysis and interpretation, Estimation of different types of heterosis, inbreeding depression and interpretation;
- A, B and C Scaling test;
- L × T analysis and interpretation, QTL analysis;
- Use of computer packages;
- Diallel analysis;
- G × E interaction and stability analysis.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures,
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After studying this course, the student will be equipped with the knowledge of additive dominance and epistatic gene action. He will also be introduced with the various designs for analysis of genotypic and phenotypic variance and QTL mapping.

X. Suggested Reading

Bos I and Caligari P. 1995. *Selection Methods in Plant Breeding*. Chapman & Hall.

Falconer DS and Mackay J. 1998. *Introduction to Quantitative Genetics* (3rd Ed.).ELBS/ Longman, London.
Mather K and Jinks JL.1985. *Biometrical Genetics* (3rd Ed.). Chapman and Hall, London.
Nandarajan N and Gunasekaran M. 2008. *Quantitative Genetics and Biometrical Techniques in Plant Breeding*. Kalyani Publishers, New Delhi.
Naryanan SS and Singh P. 2007. *Biometrical Techniques in Plant Breeding*. Kalyani Publishers, New Delhi.
Roy D. 2000. *Plant Breeding: Analysis and Exploitation of Variation*. Narosa Publishing House, New Delhi.
Sharma JR. 2006. *Statistical and Biometrical Techniques in Plant Breeding*. New Age International Pvt. Ltd.
Singh P and Narayanan SS. 1993. *Biometrical Techniques in Plant Breeding*. Kalyani Publishers, New Delhi.
Singh RK and Chaudhary BD. 1987. *Biometrical Methods in Quantitative Genetic* analysis. Kalyani Publishers, New Delhi.
Weir DS. 1990. *Genetic Data Analysis. Methods for Discrete Population Genetic Data*. Sinauer Associates.
Wricke G and Weber WE. 1986. *Quantitative Genetics and Selection in Plant Breeding*. Walter de Gruyter.

e-Suggested Reading

www.iasri.icar.gov.in
www.hau.ac.in/OPstat

I. Course Title : Varietal Development and Maintenance Breeding
II. Course Code : GPB 504
III. Credit Hours : 2(1+1)

IV. Why this course?

It is an indispensable course which apprise the students about various practices and procedures in the development of a variety and steps to maintain the purity of varieties/ hybrids. Further, it provides basics of nucleus and breeder seed production techniques.

V. Aim of the course

The purpose of this course is to make students well acquainted with the techniques and procedures of varietal development. He will be associated with development of variety so the course aims is to provide knowledge on DUS testing, protocols of various breeding techniques, procedures of release of variety, maintenance of the variety and production of nucleus and breeder seed of variety/ hybrids.

VI. Theory

Unit I

Variety Development systemsand Maintenance; Definition- variety, cultivar, extant variety, essentially derived variety, independently derived variety, reference variety, farmers’ variety, landraces, hybrid, and population; Variety testing, release and notification systems and norms in India and abroad.

Unit II

DUS testing- DUS Descriptors for major crops; Genetic purity concept and maintenance breeding. Factors responsible for genetic deterioration of varieties - safeguards during seed production.

Unit III

Maintenance of varieties in self and cross pollinated crops, isolation distance; Principles of seed production; Methods of nucleus and breeder seed production; Generation system of seed multiplication -nucleus, breeders, foundation, certified.

Unit IV

Quality seed production technology of self and cross-pollinated crop varieties, viz., cereals and millets (wheat, barley, paddy, pearlmillet, sorghum, maize and ragi, etc.); Pulses (greengram, blackgram, cowpea, pigeonpea, chickpea, fieldpea, lentil); Oilseeds (groundnut, soybean, sesame, castor, sunflower, safflower, linseed, rapeseed and mustard); fibres (cotton/ jute) and forages (guar, forage sorghum, teosinte, oats, berseem, lucerne).

Unit V

Seed certification procedures; Seed laws and acts, plant variety protection regulations in India and international systems.

VII. Practical

- Identification of suitable areas/ locations for seed production;
- Ear-to-row method and nucleus seed production;
- Main characteristics of released and notified varieties, hybrids and parental lines;
- PGMS and TGMS;
- Identification of important weeds/ objectionable weeds;
- Determination of isolation distance and planting ratios in different crops; Seed production techniques of varieties in different crops;
- Hybrid seed production technology of important crops;
- DUS testing and descriptors in major crops;
- Variety release proposal formats in different crops.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

Pass out student will have complete knowledge on the various procedures linked with the development and release of variety. This course will also enable student how to maintain and multiply variety for large scale distribution. It will also make student acquainted with the seed laws and acts related to plant variety protection.

X. Suggested Reading

Agarwal RL. 1997. *Seed Technology*. 2nd Ed. Oxford & IBH.

Kelly AF. 1988. *Seed Production of Agricultural Crops*. Longman.

McDonald MB Jr and Copeland LO. 1997. *Seed Production: Principles and Practices*. Chapman & Hall.

Poehlman JM and Borthakur D. 1969. *Breeding Asian Field Crops*. Oxford & IBH.

Singh BD. 2005. *Plant Breeding: Principles and Methods*. Kalyani. 2015

Thompson JR. 1979. *An Introduction to Seed Technology*. Leonard Hill

I. Course Title : Principles of Cytogenetics

II. Course Code : GPB 505

III. Credit Hours : 3 (2+1)

IV. Why this course?

The very purpose of this course is to acquaint the students with cell cycle and architecture of chromosome in prokaryotes and eukaryotes, special types of chromosomes, techniques for karyotyping. This course aims to impart knowledge of variations in chromosomes numbers and their structures. It acquaints the students for the production and use of haploids, apomictic populations and their role in genetics and breeding.

V. Aim of the course

To provide insight into structure and functions of chromosomes, chromosome mapping, polyploidy and cytogenetic aspects of crop evolution.

VI. Theory

Unit I

Cell cycle and architecture of chromosome in prokaryotes and eukaryotes; Chromonemata, chromosome matrix, chromomeres, centromere, secondary constriction and telomere; artificial chromosome construction and its uses; Special types of chromosomes.Variation in chromosome structure: Evolutionary significance; Introduction to techniques for karyotyping; Chromosome banding and painting -*In situ* hybridization and various applications.

Unit II

Structural and numerical variations of chromosomes and their implications; Symbols and terminologies for chromosome numbers, euploidy, haploids, diploids and polyploids; Utilization of aneuploids in gene location; Variation in chromosome behaviour, somatic segregation and chimeras, endomitosis and somatic reduction; Evolutionary significance of chromosomal aberrations, balanced lethal and chromosome complexes; Inter-varietal chromosome substitutions.

Unit III

Fertilization barriers in crop plants at pre-and postfertilization levels; *In-vitro* techniques to overcome the fertilization barriers in crops; Polyploidy. Genetic consequences of polyploidization and role of polyploids in crop breeding; Evolutionary advantages of autopolyploid *vs* allopolyploids; Role of aneuploids in basic and applied aspects of crop breeding, their maintenance and utilization in gene mapping and gene blocks transfer; Alien addition and substitution lines, creation and utilization; Apomixis, evolutionary and genetic problems in crops with apomixes.

Unit IV

Reversion of autopolyploid to diploids; Genome mapping in polyploids; Interspecific hybridization and allopolyploids; Synthesis of new crops (wheat, *Triticale, Brassica*, and cotton); Hybrids between species with same chromosome number, alien translocations; Hybrids between species with different chromosome number; Gene transfer using amphidiploids, bridge species.

Unit V

Chromosome manipulations in wide hybridization; case studies; Production and use of haploids, dihaploids and doubled haploids in genetics and breeding.

VII. Practical

- Learning the cytogenetical laboratory techniques, various chemicals to be used for fixation, dehydration, embedding, staining, cleaning, etc.;
- Microscopy: various types of microscopes;
- Preparing specimen for observation;
- Fixative preparation and fixing specimen for light microscopy studies in cereals;
- Studies on mitosis and meiosis in crop plants;
- Using micrometres and studying the pollen grain size in various crops. Pollen germination *in vivo* and *in-vitro*;
- Demonstration of polyploidy.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

The course will provide full knowledge to the student on the various procedures linked with cell development and chromosome structure and function. This course will also enable student how to tailor and utilize the variation in chromosome number and structures in the development and synthesis of new species and varieties.

X. Suggested Reading

Becker K and Hardin J. 2004. *World of the Cell*. 5th Ed. Pearson Edu. 9th edition.
Carroll M. 1989. *Organelles*. The Guilford Press.
Charles B. 1993. *Discussions in Cytogenetics*. Prentice Hall Publications.
Darlington CD and La Cour LF. 1969. *The Handling of Chromosomes*. George Allen & Unwin Ltd.
Elgin SCR. 1995. *Chromatin Structure and Gene Expression*. IRLPress,Oxford.
Gupta PK and Tsuchiya T. 1991. *Chromosome Engineering in Plants: Genetics, Breeding and Evolution*. Part A.
Gupta PK. 2010. *Cytogenetics*. Rastogi Pubishers.
Johannson DA. 1975. *Plant Micro technique*. McGraw Hill.
Karp G. 1996. *Cell and Molecular Biology: Concepts and Experiments*. John Wiley & Sons.
Khush GS. 1973. *Cytogenetics of aneuploids*. Elsevier. 1 edition.
Roy D.2009. *Cytogenetics*. Alpha Science Intl Ltd.
Schulz SJ.1980. *Cytogenetics- Plant, animals and Humans*. Springer.
Sharma AK and Sharma A. 1988. *Chromosome Techniques: Theory and Practice*. Butterworth-Heinemann publisher 2014.3rd edition
Singh RJ. 2016. Plant *Cytogenetics* 3rd Edition. CRC Press.
Sumner AT. 1982. *Chromosome Banding*. Unwin Hyman Publ. 1 edition, Springer pub.
Swanson CP. 1960. *Cytology and Cytogenetics*. Macmillan & Co.

I. Course Title : Molecular Breeding and Bioinformatics*
II. Course Code : GPB 506
III. Credit Hours : 3(2+1)

IV. Why this course?

The course will provide deep knowledge to the students on genotyping and kinds of markers including biochemical and molecular, mapping populations, allele mining. This will also add ways to perform marker-assisted selection and gene pyramiding to evolve superior varieties.

V. Aim of the course

To impart knowledge and practical skills to use innovative approaches and Bioinformatics in Plant Breeding.

VI. Theory

Unit I

Genotyping; Biochemical and Molecular markers; Morphological, biochemical and DNA-based markers (RFLP, RAPD, AFLP, SSR, SNPs, ESTs, etc.), Functional markers; Mapping populations (F_2s, back crosses, RILs, NILs and DH); Molecular mapping and tagging of agronomically important traits; Statistical tools in marker analysis.

Unit II

Allele mining; Marker-assisted selection for qualitative and quantitative traits; QTLs analysis in crop plants; Marker-assisted backcross breeding for rapid introgression; Genomics- assisted breeding; Generation of EDVs; Gene pyramiding.

Unit III

Introduction to Comparative Genomics; Large scale genome sequencing strategies; Human genome project; Arabidopsis genome project; Rice genome project; Comparative genomics tools; Introduction to proteomics; 2D gel electrophoresis; chromatography and sequencing by Edman degradation and mass spectrometry; Endopeptidases; Nanotechnology and its applications in crop improvement.

Unit IV

Recombinant DNA technology, transgenes, method of transformation, selectable markers and clean transformation techniques, vector-mediated gene transfer, physical methods of gene transfer; Production of transgenic plants in various field crops: cotton, wheat, maize, rice, soybean, oilseeds, sugarcane, etc. and commercial releases; Biotechnology applications in male sterility/ hybrid breeding, molecular farming; Application of Tissue culture in molecular breeding; MOs and related issues (risk and regulations); GMO; International regulations, biosafety issues of GMOs; Regulatory procedures in major countries including India, ethical, legal and social issues; Intellectual property rights; Introduction to bioinformatics: bioinformatics tools, biological data bases (primary and secondary), implications in crop improvement.

VII. Practical

- Requirements for plant tissue culture laboratory;
- Techniques in plant tissue culture;
- Media components and media preparation;
- Aseptic manipulation of various explants, observations on the contaminants occurring in media, interpretations;
- Inoculation of explants, callus induction and plant regeneration; Standardizing the protocols for regeneration;
- Hardening of regenerated plants; Establishing a greenhouse and hardening procedures;

- Visit to commercial micropropagation unit;
- Transformation using Agrobacterium strains;
- GUS assay in transformed cells/ tissues;
- DNA isolation, DNA purity and quantification tests;
- Gel electrophoresis of proteins and isozymes, PCR-based DNA markers, gel scoring and data analysis for tagging and phylogenetic relationship;
- Construction of genetic linkage maps using computer software;
- NCBI Genomic Resources, GBFF, Swiss Prot, Blast n/ Blast p, Gene Prediction Tool, Expasy Resources, PUBMED and PMC, OMIM and OMIA, ORF finder;
- Comparative Genomic Resources: - Map Viewer (UCSC Browser and Ensembl);
- Primer designing- Primer 3/ Primer BLAST.

VIII. Teaching methods
- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

The knowledge of this course will enable the student to know about various molecular tools and approaches for genotyping and marker assisted breeding, intellectual property rights, bioinformatics tools and their uses in crop improvement.

X. Suggested Reading

Azuaje F and Dopazo J. 2005. *Data Analysis and Visualization in Genomics and Proteomics*. John Wiley and Sons.

Brown TA. 1991. *Essential Molecular Biology: a practical Approach*. Oxford university press, 2002, 2nd edition

Chawala HS. 2000. *Introduction to Plant Biotechnology*. Oxford & IBH Publishing Co. Pvt. Ltd.

Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology: Concepts, Methods and Applications*. Oxford & IBH.

Gupta PK. 1997. *Elements of Biotechnology*. Rastogi Publ.

Hackett PB, Fuchs JA and Messing JW. 1988. *An Introduction to Recombinant DNA Technology - Basic Experiments in Gene Manipulation*. 2nd Ed. Benjamin Publ. Co.

Jollès P and Jörnvall H. 2000. *Proteomics in Functional Genomics: Protein Structure Analysis*. Birkhäuser.

Lewin B. 2017. *Genes XII*. Jones & Bartlett learning, 2017.

Robert NT and Dennis JG. 2010. *Plant Tissue Culture, Development, and Biotechnology*. CRC Press.

Sambrook J and Russel D. 2001. *Molecular Cloning - a Laboratory Manual*. 3rd Ed. Cold Spring Harbor Lab. Press.

Singh BD. 2005. *Biotechnology, Expanding Horizons*. Kalyani Publishers, New Delhi.

Watson J. 2006. *Recombinant DNA*. Cold Spring harbor laboratory press.

I. Course Title : Breeding for Quality and Special Traits

II. Course Code : GPB 507

III. Credit Hours : 3(2+1)

IV. Why this course?

Quality consciousness is growing in the society and only quality products are in demand in the market so has to be the new varieties. This course acquaints breeding for grain quality parameters in field crops. It will also teach about the genetic engineering protocols for quality improvement: Biofortification in crops and Nutritional genomics and Second generation transgenics.

V. Aim of the course

To provide insight into recent advances in improvement of quality traits in cereals, millets, legumes, oilseeds, forage and industrial crops using conventional and modern biotechnological approaches.

VI. Theory

Unit I

Developmental biochemistry and genetics of carbohydrates, proteins, fats, vitamins, amino acids and anti-nutritional factors; Nutritional improvement - A human perspective.

Unit II

Breeding for grain quality parameters in rice and its analysis; Golden rice and aromatic rice: Breeding strategies, achievements and application in Indian context; Molecular basis of quality traits and their manipulation in rice; Post harvest manipulation for quality improvement; Breeding for baking qualities in wheat, characters to be considered and breeding strategies, molecular and cytogenetic manipulation for quality improvement in wheat.

Unit III

Breeding for quality improvement in Sorghum, pearl millet, barley and oats; Quality protein maize, specialty corns, concept and breeding strategies; Breeding for quality improvement in important forage crops for stay green traits; Genetic resource management for sustaining nutritive quality in crops.

Unit IV

Breeding for quality improvement in pulses – Chickpea, pigeonpea, green gram and black gram cooking quality; Breeding for quality in oilseeds -groundnut, mustard, soybean, sesame, sunflower and minor oilseeds; Molecular basis of fat formation and manipulation to achieve more PUFA in oil crops; Genetic manipulation for quality improvement in cotton. Breeding for quality improvement in Sugarcane, potato.

Unit V

Genetic engineering protocols for quality improvement: Achievements made; Biofortification in crops; Classification and importance, Nutritional genomics and Second generation transgenics.

VII. Practical

- Grain quality evaluation in rice; Correlating ageing and quality improvement in rice;
- Quality analysis in millets;
- Estimation of anti-nutritional factors like tannins in different varieties/ hybrids: A comparison;
- Quality parameters evaluation in wheat, pulses and oilseeds;
- Evaluation of quality parameters in cotton, sugarcane and potato;
- Value addition in crop plants;

- Post-harvest processing of major field crops;
- Quality improvement in crops through tissue culture techniques;
- Evaluating the available populations like RIL, NIL, etc. for quality improvement using MAS procedures;
- Successful example of application of MAS for quality trait in rice, mustard, maize, etc.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

The knowledge of this course will expose the student to know about various conventional and genetic engineering techniques for the improvement of quality characters in agricultural and horticultural field crops.

X. Suggested Reading

Chahal GS and SS Ghosal. 2002. *Principles and procedures of plant breeding - Biotechnological and Conventional approaches*, Narosa Publications Chopra VL. 1997. *Plant Breeding*. Oxford & IBH. 2018.

FAO 2001. *SpecialityRices of the World - Breeding, Production and Marketing*. Oxford & IBH,1 Nov 2001.

Ghosh P. 2004. *Fibre Science and Technology*. Tata McGraw Hill.

Gupta SK. 2007. *Advances in Botanical Research* Vol. 45 Academic Press USA.

Hay RK. 2006. *Physiology of Crop Yield*. 2nd Ed. Blackwell.

Nigam J. 1996. *Genetic Improvement of Oilseed Crops*. Oxford & IBH.

Singh BD. 1997. *Plant Breeding*. Kalyani Publishers, New Delhi.

Singh RK, Singh UK and Khush GS. 2000. *Aromatic Rices*. Oxford & IBH.

I. Course Title : Mutagenesis and Mutation Breeding

II. Course Code : GPB 508

III. Credit Hours : 3 (2+1)

IV. Why this course?

The knowledge of this course will enable the students to learn about mutation, various methods of inducing mutations and their utilization in plant breeding. It will also give in depth knowledge about genomics, allele mining, TILLING, etc. and their utilization in crop improvement programmes.

V. Aim of the course

To impart the knowledge about general principles of mutagenesis for crop improvement and various tests/ methods for detection of mutations.

VI. Theory

Unit I

Mutation and its history, nature and classification of mutations: spontaneous and induced mutations, micro and macro mutations, pre and post adaptive mutations; Detection of mutations. Paramutations in crops plants.

Unit II

Mutagenic agents: physical – radiation types and sources: Ionizing and non-ionizing radiations. Radiobiology: mechanism of action of various radiations (photoelectric absorption, Compton scattering and pair production) and their biological effects – RBE and LET relationships; Effect of mutations on DNA – repair mechanisms operating at DNA, chromosome, cell and organism level to counteract the mutation effects; Dosimetry -Objects and methods of treatment; Factors influencing mutation: dose rate, acute vs chronic irradiation, recurrent irradiation, enhancement of thermal neutron effects; Radiation sensitivity and modifying factors: External and internal sources – Oxygen, water content, temperature and nuclear volume.

Unit III

Chemical mutagens: Classification – base analogues, antibiotics, alkylating agents, acridine dyes and other mutagens: their properties and mode of action; Dose determination and factors influencing chemical mutagenesis; Treatment methods using physical and chemical mutagens, Combination treatments; other causes of mutation – direct and indirect action, comparative evaluation of physical and chemical mutagens.

Unit IV

Observing mutagen effects in M_1 generation: plant injury, lethality, sterility, chimeras, etc.; Observing mutagen effects in M_2 generation; Estimation of mutagenic efficiency and effectiveness – spectrum of chlorophyll and viable mutations; Mutations in traits with continuous variation; Factors influencing the mutant spectrum: genotype, type of mutagen and dose, pleiotropy and linkage, etc.; Individual plant based mutation analysis and working out effectiveness and efficiency in M_3 generation; Comparative evaluation of physical and chemical mutagens for creation of variability in the some species- Case studies.

Unit V

Use of mutagens in creating oligogenic and polygenic variations – Case studies; *In-vitro* mutagenesis – Callus and pollen irradiation; Handling of segregating M_2 generations and selection procedures; Validation of mutants; Mutation breeding for various traits (disease resistance, insect resistance, quality improvement, etc.) in different crops; Procedures for micromutations breeding/ polygenic mutations; Achievements of mutation breeding- varieties released across the world, problems associated with mutation breeding. Use of mutagens in genomics, allele mining, TILLING.

VII. Practical

- Precautions on handling of mutagens; Dosimetry-Studies of different mutagenic agents:Physical mutagens and Chemical mutagens;
- Learning on Radioactivity- Production source and isotopes at BRIT, Trombay, Learning about gamma chamber;
- Radiation hazards: Monitoring – safety regulations and safe transportation of radioisotopes, visit to radio isotope laboratory; learning on safe disposal of radioisotopes;
- Hazards due to chemical mutagens – Treating the plant propagules at different doses of physical and chemical mutagens;
- Procedures in combined mutagenic treatments;
- Raising the crop for observation; Mutagenic effectiveness and efficiency, calculating the same from earlier literature;

- Study of M_1 generation – Parameters;
- Study of M_2 generation – Parameters;
- Mutation breeding in cereals and pulses-achievements made and an analysis;
- Mutation breeding in oilseeds and cotton- achievements and opportunities;
- Mutation breeding in forage crops and vegetatively propagated crops;
- Procedure for detection of mutations for polygenic traits in M_2 and M_3 generations.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

This course will make the student well versed with the process of mutation and its use in crop improvement. This course will also give in depth knowledge of mutations in genomics, allele mining and TILLING.

X. Suggested Reading

Alper T. 1979. *Cellular Radiobiology*. Cambridge Univ. Press, London.

Chadwick KH and Leenhouts HP. 1981. *The Molecular Theory of Radiation Biology*. Springer-Verlag.

Cotton R, Edkin E and Forrest S. 2000. *Mutation Detection: A Practical Approach*. Oxford Univ. Press.

International Atomic Energy Agency. 1970. *Manual on Mutation Breeding*. International Atomic Energey Agency, Vienna, Italy.

Shu QY, Forster BP and Nakagawa N. 2012. *Plant Mutation Breeding and Biotechnology*. Gutecnberg Press Ltd. Rome Italy ISBN:978-925107-022-2 (FAO).

Singh BD. 2003. *Genetics*. Kalyani Publishers, New Delhi.

Strickberger MW. 2005. *Genetics*. 3rd Ed. Prentice Hall.

www.barc.gov.in

I. Course Title : Hybrid Breeding

II. Course Code : GPB 509

III. Credit Hours : 3(2+1)

IV. Why this course?

This course will expose the students with the basic concepts of hybrid varietiesand various techniques for development of hybrids in crop plants. This will also give an overview of various kinds of male sterility and their utilization in hybrid seed production of important field crops.

V. Aim of the course

To provide knowledge of understanding about mechanisms of heterosis and its exploitation for yield improvement through conventional and biotechnological approaches.

VI. Theory

Unit I

Historical aspect of heterosis, nomenclature and definitions of heterosis; Heterosis in natural population and inbred population; Evolutionary aspects – Genetic consequences of selfing, sibbing and crossing in self-and cross-pollinated and asexually propagated crops; Pre-Mendelian and Post-Mendelian ideas – Evolutionary concepts of heterosis; Genetic theories of heterosis – Physiological, Biochemical and molecular factors underlining heterosis; theories and their estimation; Biometrical basis of heterosis.

Unit II

Prediction of heterosis from various crosses, inbreeding depression, coefficient of inbreeding and its estimation, residual heterosis in F_2 and segregating populations, importance of inbreeding in exploitation of heterosis – case studies.; Relationship between genetic distance and expression of heterosis, case studies; Divergence and genetic distance analyses, morphological and molecular genetic distance in predicting heterosis; Development of heterotic pools in germplasm/ genetic stocks and inbreeds, their improvement for increasing heterosis.

Unit III

Male sterility and use in heterosis breeding; Male sterile line creation and diversification in self-pollinated, cross pollinated and asexually propagated crops; Creation of male sterility through genetic engineering and its exploitation in heterosis; Maintenance, transfer and restoration of different types of male sterility; Use of self-incompatibility in development of hybrids.

Unit IV

Hybrid seed production system: 3-line, 2-line and 1-line system; Development of inbreeds and parental lines- A, B and R lines – functional male sterility; Commercial exploitation of heterosis, maintenance breeding of parental lines in hybrids; Fixation of heterosis in self, cross and often cross pollinated crops, asexually/ clonally propagated crops, problems and prospects; Apomixis in fixing heterosis-concept of single line hybrid; Organellar heterosis and complementation.

Unit V

Hybrid breeding in wheat, rice, cotton, maize, pearl millet, sorghum and rapeseed-mustard, sunflower, safflower and castor oilseed crops and pigeonpea.

VII. Practical

- Characterization of male sterile lines using morphological descriptors;
- Restorer line identification and diversification of male sterile sources;
- Male sterile line creation in crop plants, problems in creation of CGMS system, ways of overcoming them;
- Diversification and restoration;
- Success stories of hybrid breeding in Maize, Rice, Pearl millet, Sorghum and Pigeon pea;
- Understanding the difficulties in breeding apomicts;
- Estimation of heterotic parameters in self, cross and asexually propagated crops;
- Estimation from the various models for heterosis parameters;
- Hybrid seed production in field crops—an account on the released hybrids, their potential, problems and ways of overcoming it;
- Hybrid breeding at National and International level,opportunities ahead.

VIII. Teaching methods

- Power point presentation

- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completing this course, the student will be able to know about importance of heterosis, the various conventional and biotechnological approaches for the development of hybrids. This will also enable student to know about the use of male sterility in hybrid seed production of important field crops.

X. Suggested Reading

Agarwal RL. 1998. *Fundamental of Plant Breeding and hybrid Seed Production*. Science Publisher London.

Akin E. 1979. *The Geometry of Population Genetics*. Springer-Verlag.

Ben HL. 1998. *Statistical Genomics – Linkage, Mapping and QTL Analysis*. CRC Press.

Chal GS and Gossal SS. 2002. *Principles and procedures of Plant Breeding, Biotechnology and Convetional Approaches*. Narosa Publishing House. New Delhi

De JG. 1988. *Population Genetics and Evolution*. Springer-Verlag. 30 January 2012

Hartl DL. 2000. *A Primer of Population Genetics*. 3rd Ed. Sinauer Assoc.

Mettler LE and Gregg TG. 1969. *Population Genetics and Evolution*. Prentice-Hall. 25 April 1988

Montgomery DC. 2001. *Design and Analysis of Experiments*. 5th Ed., Wiley & Sons. 2013

Mukherjee BK. 1995.*The Heterosis Phenomenon*. Kalyani Publishers, New Delhi.

Proceedings of *Genetics and Exploitation of Heterosis in Crops* – An International Symposium CIMMYT, 1998.

Richards AJ. 1986. *Plant Breeding Systems*. George Allen & Unwin. 30 May 1997

Singh BD. 2006. *Plant Breeding*. Kalyani Publishers, New Delhi.

Srivastava S and Tyagi R. 1997. *Selected Problems in Genetics*. Vols. I, II. Anmol Publ.

Virmani SS. 1994. *Heterosis and Hybrid Rice Breeding. Monographs of "Theoretical and Applied Genetics*", Springer-Verlag.

I. Course Title : Seed Production and Certification

II. Course Code : GPB 510

III. Credit Hours : 2(1+1)

IV. Why this course?

Seed is the essence of life. Its improvement, production and maintenance is an essential feature of any variety. Seed chain concept is highly relevant in commercial promotion of new varieties whereas process of certification is mandatory for quality assurance of seed.

V. Aim of the course

To impart knowledge on principles of seed production and certification. This will help the students to understand seed production practices and seed certification procedures in different crops.

VI. Theory

Unit I

Importance of seed as basic input in agriculture; Seed quality concept and importance; Generation system of seed multiplication -Varietal replacement rate, Seed multiplication ratios, Seed replacement rate, Seed renewal period and seed demand

and supply; Various factors influencing seed production –Physical and Genetic purity in seed production; Factors responsible for varietal and genetic deterioration.

Unit II

Nucleus seed production and its maintenance - Maintenance of parental lines of hybrids, Production of breeder, foundation and certified seed and their quality maintenance; Principles of seed production in self- and cross-pollinated crops; Hybrid seed production - system and techniques involved in Seed village concept; Organic seed production and certification.

Unit III

Principles of seed production in field crops; Floral structure, pollination mechanism and seed production techniques in self- and cross-pollinated cereals and millets.

Unit IV

Floral structure, pollination mechanism and methods and techniques of seed production in major pulses and oilseed crops; Varietal and hybrid seed production techniques in Pigeon pea, Mustard, Castor and Sunflower.

Unit V

Floral structure, pollination mechanism and methods and techniques of seed production in major commercial fibres. Hybrid-seed production techniques in major vegetatively propagated crops.

Unit VI

Seed certification - history, concept, objectives;Central seed certification board Seed certification agency/ organization and staff requirement; Legal status - Phases of seed certification, formulation, revision and publication of seed certification standards; Minimum Seed Certification Standards (MSCS) for different crops - General and specific crop standards, Field and seed standards; Planning and management of seed certification programs; Eligibility of a variety for certification, area assessment, cropping history of the seed field.

VII. Practical

- Planting design for variety- hybrid seed production techniques, planting ratio of male and female lines, synchronization of parental lines and methods to achieve synchrony;
- Identification of rogues and pollen shedders, supplementary pollination, detasseling, hand emasculation and pollination;
- Pollen collection and storage methods, pollen viability and stigma receptivity;
- Pre-harvest sanitation, maturity symptoms, harvesting techniques;
- Visits to seed production plots - visit to seed industries;
- Planning for seed production: cost benefit ratio, seed multiplication ratio and seed replacement rate;
- General procedure of seed certification, identification of weed and other crop seeds as per specific crops, field inspection at different stages of a crop and observations recorded on contaminants and reporting of results, inspection and sampling, harvesting/ threshing, processing and after processing for seed law enforcement;
- Specifications for tags and labels to be used for certification purpose.

VIII. Teaching methods

- Power point presentation

- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completing this course the student will be able to know about seed production of different crop varieties and hybrids, their processing, marketing and seed laws.

X. Suggested Reading

Agrawal PK and Dadlani M. 1987. *Techniques in Seed Science and Technology*, South Asian Publishers, Delhi.
Agrawal RL. 1997. *Seed Technology,* Oxford & IBH Publishing.
Anon, 1965. *Field Inspection Manual and Minimum Seed Certification Standards*, NSC Publication, New Delhi.
Anon. 1999. *Manual of Seed Certification procedures.* Directorate of Seed Certification, Coimbatore, Tamil Nadu.
Joshi AK and Singh BD. 2004. *Seed Science and Technology*, Kalyani Publishers, New Delhi.
Kelly AF. 1988. *Seed Production of Agricultural Crops*. John Wiley, New York.
Mc Donald MB and Copeland LO. 1997. *Seed Science and Technology*, Scientific Publisher, Jodhpur.
Ramamoorthy K, Sivasubramaniam K and Kannan M. 2006. *Seed Legislation in India*. Agrobios (India), Jodhpur, Rajasthan.
Singhal NC. 2003. *Hybrid Seed Production in Field Crops*, Kalyani Publications, New Delhi
Tunwar NS and Singh SV. 1988. *Indian Minimum Seed Certification Standards*. Central Seed Certification Board, Ministry of Agriculture, New Delhi.

e-Resources

www.gov.mb.ca
www.agricoop.nic.in
www.agri.nic.in
www.fao.org
www.seednet.gov.in

I. Course Title : Crop Breeding I (*Kharif* Crops)
II. Course Code : GPB 511
III. Credit Hours : 3(2+1)

IV. Why this course?

Botanical features, reproductive systems, genetics involved and important breeding techniques are essential to undertake any crop improvement programme. This course is designed for important/ major *Kharif* field crops.

V. Aim of the course

To provide insight into recent advances in improvement of kharif cereals, legumes, oilseeds, fibre, sugarcane and vegetative propagated crops using conventional and modern biotechnological approaches.

VI. Theory

Unit I

Rice: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement, Aerobic rice, its implications and drought resistance breeding.

Maize: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, releasedvarieties, examples of MAS used for improvement- QPM and Bt maize – strategies and implications.

Small millets: Evolution and distribution of species and forms - wild relatives and germplasm; Cytogenetics and genome relationship - breeding objectives yield, quality characters, biotic and abiotic stress resistance, etc.

Unit II

Pigeon pea: evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement - Hybrid technology; maintenance of male sterile, fertile and restorer lines, progress made at National and International institutes.

Groundnut: Origin, evolution mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship, breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Other pulses: Urdbean, mungbean, cowpea,: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship, breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), released varieties, examples of MAS used for improvement. Interspecific crosses attempted and its implications, reasons for failure, ways of overcoming them.

Unit III

Soybean: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement.

Castor and Sesame: Origin, evolution mode of reproduction, chromosome number; Genetics –cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), released varieties, examples of MAS used for improvement; Hybrid breeding in castor – opportunities, constraints and achievements.

Unit IV

Cotton: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement, Development and maintenance of male sterile lines – Hybrid development and seed production – Scenario of Bt cottons, evaluation procedures for Bt cotton.

Jute: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement.

Unit V

Sugarcane: Evolution and distribution of species and forms, wild relatives and germplasm; Cytogenetics and genome relationship – Breeding objectives- yield, quality characters, biotic and abiotic stress resistance, etc.

Forage crops: Evolution and distribution of species and forms – Wild relatives and germplasm; Cytogenetics and genome relationship; Breeding objectives- yield, quality characters and palatability studies; Biotic and abiotic stress resistance, etc.

Seed spices: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement; Achievements of important spice crops.

VII. Practical

- Floral biology, emasculation, pollination techniques in rice, maize, pigeon pea, soybean, sesame, cotton;
- Study of range of variation for yield and yield components;
- Study of segregating populations in cereal, pulses and oilseed crops;
- Learning on the crosses between different species; attempting crosses between black gram and green gram;
- Evaluating the germplasm of cotton for yield, quality and resistance parameters, learning the procedures on development of Bt cotton;
- Visit to Cotton Technology Laboratory and Spinning Mills;
- Learning on the Standard Evaluation System (SES) and descriptors; Use of software for database management and retrieval;
- Practical learning on the cultivation of fodder crop species on sewage water, analysing them for yield components and palatability;
- Laboratory analysis of forage crops for crude protein, digestibility percent and other quality attributes;
- Visit to animal feed producing factories;
- Learning the practice of value addition; Visiting the animal husbandry unit and learning the animal experiments related with palatability and digestibility of fodder.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures

- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completing this course, the student will be able to know about important botanical status and reproductive structures of crops and genetics of important kharif field crops.

X. Suggested Reading

Agarwal RL. 1996. *Identifying Characteristics of Crop Varieties*. Oxford & IBH.

Bahl PN and Salimath PM. 1996. *Genetics, Cytogenetics and Breeding of Crop Plants*. Vol. I. *Pulses and Oilseeds*. Oxford & IBH.

Chandraratna MF. 1964. *Genetics and Breeding of Rice*. Longmans.

Chopra VL and Prakash S. 2002. *Evolution and Adaptation of Cereal Crops*. Oxford & IBH.

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IRRI. 1964. *Rice Genetics and Cytogenetics*. Elsevier.

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Jennings PR, Coffman WR and Kauffman HE. 1979. *Rice Improvement*. IRRI, Los Banos, Manila, Philippines.

Kannaiyan S, Uthamasamy S, Theodore RK and Palaniswamy S. 2002. *New Dimensions and Approaches for Sustainable Agriculture*. Directorate of Extension Education, TNAU, Coimbatore.

Murty DS, Tabo R and Ajayi O. 1994. *Sorghum Hybrid Seed Production and Management*. ICRISAT, Patancheru, India.

Nanda JS. 1997. *Manual on Rice Breeding*. Kalyani Publishers.

Parthasarathy VA. 2017. *Spices and Plantation Crops Vol.1* (*Part A*) *Breeding of Horticultural Crops* Vol.1 (Part-B), Today and Tomorrow Printers and Publishers

Poehlman, JM. 1987. *Breeding of Field Crops*. AVI Publishing Co. Inc. East Post Connecticut, USA.

Ram HH and Singh HG. 1993. *Crop Breeding and Genetics*. Kalyani.

Sharma, AK. 2005. *Breeding Technology of Crop Plant*. Yesh Publishing House, Bikaner

Slafer GA. (Ed.). 1994. *Genetic Improvement of Field Crops*. Marcel Dekker.

Singh HG, Mishra SN, Singh TB, Ram HH and Singh DP. (Eds.). 1994. *Crop Breeding in India*. International Book Distributing Co.

Walden DB. 1978. *Maize Breeding and Genetics*. John Wiley & Sons.

I. Course Title : Crop Breeding-II (*Rabi* Crops)

II. Course Code : GPB 512

III. Credit Hours : 3(2+1)

IV. Why this course?

Botanical features, reproductive systems, genetics involved and important breeding techniques are essential to undertake any crop improvement programme. This course is designed for important/ major Rabi field crops.

V. Aim of the course

To provide insight into recent advances in improvement of *Rabi* cereals, legumes, oilseeds, fibre and vegetative propagated crops using conventional and modern biotechnological approaches

VI. Theory

Unit I

Wheat: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement.

Oats: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Barley: Origin, evolution, center of origin, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Unit II

Chickpea: Origin, evolution mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Other pulses: Lentil, field pea, Rajma, Horse gram: Origin, evolution, mode of reproduction, chromosome number; Genetics. cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement. Interspecific crosses attempted and its implications, reasons for failure, ways of overcoming them.

Unit III

Rapeseed and Mustard: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives; yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement, Oil quality, Improvement for oil quality.

Sunflower, Safflower: Origin, mode of reproduction, chromosome number; Genetics, cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement.

Unit IV

Mesta and minor fibre crops: Origin, mode of reproduction, chromosome number;

Genetics–cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Forage crops: Origin, evolution mode of reproduction, chromosome number; Genetics–cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance.

Unit V

Seed spices: Origin, evolution, mode of reproduction, chromosome number; Genetics–cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, scope of heterosis breeding, released varieties, examples of MAS used for crop improvement.

VII. Practical

- Floral biology, emasculation and pollination techniques in wheat, oats, barley, chickpea, rajma, rapeseed mustard, sunflower;
- Study of range of variation for yield and yield components;
- Study of segregating populations in cereal, pulses and oilseed crops;
- Use of descriptors for cataloguing; Learning on the crosses between different species;
- Trait based screening for stress resistance;
- Learning on the Standard Evaluation System (SES) and descriptors;
- Use of software for database management and retrieval.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the student will be able to know about the different breeding methods and genetics of major *Rabi* field crops.

X. Suggested Reading

Agarwal RL. 1996. *Identifying Characteristics of Crop Varieties*. Oxford & IBH.

Bahl PN and Salimath PM. 1996. *Genetics, Cytogenetics and Breeding of Crop Plants*. Vol. I. *Pulses and Oilseeds*. Oxford & IBH.

Gupta SK. 2012. *Technological Innovations in Major World Oil crops*. Vol. I. Springer, USA.

Gupta SK. 2012. *Technological Innovations in Major World Oil crops*. Vol. II. Springer, USA.

Gupta SK. 2016. *Breeding of Oilseed Crops for Sustainable Production*. Academic Press, USA.

Kannaiyan S, Uthamasamy S, Theodore RK and Palaniswamy S. 2002. *New Dimensions and Approaches for Sustainable Agriculture*. Directorate of Extension Education, TNAU, Coimbatore.

Parthasarathy VA. 2017. *Spices and Plantation Crops* Vol.1 (Part A) *Breeding of Breeding and Genetics*. John Wiley & Sons.

I. Course Title : Breeding Vegetable Crops
II. Course Code : GPB 513
III. Credit Hours : 3(2+1)

IV. Why this course?

This course enables the students to learn about breeding objectives, methodologies and genetics involved for the improvement of major vegetable crops.

V. Aim of the course

To educate about principles and practices adopted for breeding of vegetable crops.

VI. Theory

Unit I

Breeding for Leafy vegetables: Amaranth, chenopods and lettuce.

Unit II

Breeding for Cucurbits: Gourds, melons, pumpkins and squashes.

Unit III

Breeding for Solanaceae: Potato and tomato, eggplant, hot pepper, sweet pepper

Unit IV

Breeding for Cole crops: Cabbage, cauliflower, broccoli and knolkhol.
Breeding for Root vegetables: Carrot, beetroot, radish, sweet potato and tapioca.

Unit V

Breeding for other vegetable crops: Peas, beans, onion, garlic and okra.

VII. Practical

- Selection of desirable plants from breeding population, observations and analysis of various qualitative and quantitative traits in germplasm;
- Hybridization and handling segregating generations;
- Induction of flowering, palanological studies, selfing and crossing techniques in vegetable crops;
- Hybrid seed production of vegetable crops in bulk;
- Screening techniques for insect-pests, disease and environmental stress resistance in vegetable crops;
- Demonstration of sib-mating and mixed population;
- Molecular marker techniques to identify useful traits in the vegetable crops and special breeding techniques;
- Visit to breeding blocks, MAS for incorporating traits governed by major and polygenes.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the students will be able to know about the different breeding methods and genetics of major vegetable crops.

X. Suggested Reading

Allard RW. 1999. *Principles of Plant Breeding*. John Wiley & Sons.

Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable Crops: Breeding and Seed Production*. Vol. I. Kalyani Publishers, New Delhi.

Kalloo G. 1988. *Vegetable Breeding*. Vols. I-III. CRC Press.

Kalloo G. 1998. *Vegetable Breeding*. Vols. I-III (Combined Ed.). Panima Edu. Book Agency.

Peter KV and Pradeep KT. 2008. *Genetics and Breeding of Vegetables*. ICAR.

Rai N and Rai M. 2006. *Heterosis Breeding in Vegetable Crops*. New India Publication Agency.

Ram HH. 2005. *Vegetable Breeding-Principles and Practices*. Kalyani Publishers

Sharma JP. 2010. *Principles of Vegetable Breeding*. Kalyani Publishers, New Delhi.

Singh BD. 1983. *Plant Breeding*. Kalyani Publishers

I. Course Title : Breeding Fruit Crops

II. Course Code : GPB 514

III. Credit Hours : 3(2+1)

IV. Why this course?

This course is aimed to educate the students about the breeding strategies and avenues in Fruit crops.

V. Aim of the course

To educate students about principles and practices adopted for breeding of fruit crops.

VI. Theory

Unit I

Fruit crop breeding: History, importance of fruit breeding, centers of diversity, distribution, domestication and adaptation of commercially important fruits.

Unit II

Issues in fruit crop breeding – heterozygosity, polyploidy, polyembryony, parthenocarpy and seed lessness, incompatibility and sterility systems.

Unit III

Apomixis - merits and demerits, types, variability for economic traits, role of genetic engineering and biotechnology in improvement of fruit crops.

Unit IV

Crop improvement in Mango, Banana, Citrus, Grapes, Papaya, Sapota and Pomegranate, Pineapple and Guava, Apple and other Rosaceous crops andregion specific fruit crops.

VII. Practical

- Germplasm documentation;
- Floral biology of mango, guava, citrus, grape, pomegranate, pollen viability in major fruit crops;
- Pollen germination to study time of anthesis and stigma receptivity;
- Hybridization technique in important fruit crops, hybrid seed collection and raising;
- Colchicine treatment for induction of polyploidy;
- Exposure to resistance breeding and screening techniques;

- Mutation breeding practices raising and evaluation of segregating populations;
- Use of mutagens to induce mutations and polyploidy;
- Visit to Biotechnology Lab and study of *in-vitro* breeding techniques.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the students will be able do the breeding of fruit crops through various conventional and biotechnological methods besides mutation breeding.

X. Suggested Reading

Bhojwani SS and Razdan MK. 2006. *Plant Tissue Culture -Theory and Practice*. Elsevier Publication, Amesterdam.
Chadha KL and Pareek, OP. 1996. (Eds.). *Advances in Horticulture*. Vol. I to IV. Malhotra Publ. House, New Delhi.
Chadha KL and Shikhamany SD. 1999. *The Grape: Improvement, Production and Post-Harvest Management*. Malhotra Publ. House, New Delhi.
Janick and Moore JN. 1996. *Advances in Fruit Breeding*, AVI Pub., USA.
Janick J and Moore JN. 1996. *Fruit Breeding*. Vols. I to III. John Wiley & Sons.
Kumar N. 2006. *Breeding of Horticultural Crops - Principles and Practices*. New India Publishing Agency, New Delhi.
Moore JN and Janick Jules. 1996. *Methods in Fruit Breeding*. Purdue University Press, South Campus Court D., USA.
Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK. and Mohanadas S. 2001. *Biotechnology of Horticultural Crops*. Vols. I-III. Naya Prokash, Kolkata.
Ray PK. 2002. *Breeding of Tropical and Sub-tropical Fruits*. Narosa Publishing House, New Delhi.
Simmonds NW. 1976. *Evolution of Crop Plants*, Orient Longman, London.

I. Course Title : Breeding Ornamental Crops

II. Course Code : GPB 515

III. Credit Hours : 3(2+1)

IV. Why this course?

The course will impart knowledge to student about breeding of Ornamental Crops through conventional and biotechnological interventions.

V. Aim of the course

To educate about principles and practices adopted for breeding of ornamental crops.

VI. Theory

Unit I

History of improvement of ornamental plants; Centre of origin of ornamental crop; Objectives and techniques in ornamental plant breeding.

Unit II

Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops, viz., Rose, Jasmine, *Chrysanthemum*, Tuberose, *Gerbera*, *Gladiolus*, *Dahlia*, *Lilium*, *Gaillardia*, *Petunia*, *Bouganvillea*, Pansy, Marigold, *Geranium*, *Antirrhinum*, China aster, Orchids, *Carnation*, *Hibiscus,* etc.

Unit III

Development of promising cultivars of important ornamental and flower crops; Role of Heterosis and its exploitation, production of F_1 hybrids and utilization of male sterility.

Unit IV

Production of open pollinated seeds, harvesting, processing and storage of seeds; Seed certification.

VII. Practical

- Study of floral biology and pollination in important species and cultivars of ornamental crops;
- Techniques of inducing polyploidy and mutation;
- Production of pure and hybrid seed;
- Methods of breeding suited to seed propagated plants;
- Polyploidy and mutations to evolve new varieties;
- Breeding methods for biotic and abiotic stresses;
- Visit to research institutes involved in ornamental crop breeding.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the students will be able to do the breeding of ornamental crops by conventional breeding and biotechnological methods and to know the genetics of major ornamental crops.

X. Suggested Reading

Alexander V. 2002. *Breeding for ornamentals: Classical and Molecular Approaches*. Kluwer Academic Publishers, London.

Allard RW. 1999. *Principles of Plant Breeding*. John Wiley & Sons. INC. New York.

Bhattacharjee SK and De LC. 2003. *Advanced Commercial Floriculture* Vol. 1. Aavishkar Publishers & Distributors, Jaipur.

Bose TK and Yadav LP. 2003. *Commercial Flowers*. Naya Prokash Publishers, Kolkata.

Chadha KL and Bhattacharjee SK. *Advances in Horticulture* Vol. 12, Malhotra Publishing House, New Delhi.

Mc Donald MB and Kwong FY. 2005. *Flower Seeds Biology and Technology*, CABI Publishing, Oxfordshire, UK.

Watts L.1980. *Flower and Vegetable Plant Breeding*. Grower Books

I. Course Title : Breeding for Stress Resistance and Climate Change

II. Course Code : GPB 516

III. Credit Hours : 3(2+1)

IV. Why this course?

Climate change is a big challenge to sustain higher crop productivity and nutritional quality. Concept of breeding for stress tolerance and development of hybrids/ varieties for climate change is of prime importance in plant breeding. Therefore this course is essential for budding plant breeders.

V. Aim of the course

To apprise about various abiotic and biotic stresses influencing crop yield, mechanisms and genetics of resistance and methods to breed stress tolerant varieties.

VI. Theory

Unit I

Concept and impact of climatic change; Importance of plant breeding with special reference to biotic and abiotic stress resistance; Classification of biotic stresses – major pests and diseases of economically important crops.

Unit II

Concepts of resistance to insect and pathogen resistance; Analysis and inheritance of resistance variation; Host defence responses to pathogen invasions- Biochemical and molecular mechanisms; Acquired and induced immunity and systemic acquired resistance (SAR); Host-pathogen interaction, gene-for-gene hypothesis, molecular evidence for its operation and exceptions; Concept of signal transduction and other host-defence mechanisms against viruses and bacteria.

Unit III

Types and genetic mechanisms of resistance to biotic stresses –Horizontal and vertical resistance in crop plants; Quantitative resistance/ adult plant resistance and slow rusting resistance; Classical and molecular breeding methods - Measuring plant resistance using plant fitness; Behavioural, physiological and insect gain studies; Phenotypic screening methods for major pests and diseases; Recording of observations; Correlating the observations using marker data – Gene pyramiding methods and their implications.

Classification of abiotic stresses - Stress inducing factors, moisture stress/ drought and water logging and submergence; Acidity, salinity/ alkalinity/ sodicity; High/ low temperature, wind, etc.; Stress due to soil factors and mineral toxicity; Physiological and Phenological responses; Emphasis of abiotic stresses in developing breeding methodologies.

Unit IV

Genetics of abiotic stress resistance; Genes and genomics in breeding cultivars suitable to low water regimes and water logging and submergence, high and low/ freezing temperatures; Utilizing MAS procedures for identifying resistant types in important crops like rice, sorghum, wheat, cotton, etc.; Breeding for resistance to stresses caused by toxicity, deficiency and pollutants/ contaminants in soil, water and environment.

Unit V

Use of crop wild relatives as a source of resistance to biotic and abiotic factors in major field crops; Transgenics in management of biotic and abiotic stresses, use of toxins, protease inhibitors, lectins, chitinases and Bt for diseases and insect pest management.

VII. Practical

- Understanding the climatological parameters and predisposal of biotic and abiotic stress factors- ways of combating them for diseases caused by fungi and bacteria;
- Symptoms and data recording; use of MAS procedures;
- Phenotypic screening techniques for sucking pests and chewing pests – Traits to be observed at plant and insect level;
- Phenotypic screening techniques for nematodes and borers; Ways of combating them;
- Evaluating the available populations like RIL, NIL, etc. for pest resistance;
- Use of standard MAS procedures. Breeding strategies - Weeds – ecological, environmental impacts on the crops;
- Breeding for herbicide resistance;
- Screening crops for drought and flood resistance; factors to be considered and breeding strategies;
- Screening varieties of major crops for acidity and alkalinity- their effects and breeding strategies;
- Screening forage crops for resistance to sewage water and tannery effluents; Quality parameters evaluation.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the student will be able to well verse with the stress and its causes. This will enable the students for the development of RIL, NIL, etc. for pest resistance and Use of standard MAS procedures

X. Suggested Reading

Blum A. 1988. *Plant Breeding for Stress Environments*. CRC Press.

Christiansen MN and Lewis CF. 1982. *Breeding Plants for Less Favourable Environments*. Wiley International.

Fritz RS and Simms EL. (Eds.). 1992. *Plant Resistance to Herbivores and Pathogens: Ecology, Evolution and Genetics*. The University of Chicago Press.

Li PH and Sakai A. 1987. *Plant Cold Hardiness*. Liss, New York Springer

Luginpill P. 1969. *Developing Resistant Plants - The Ideal Method of Controlling Insects*. USDA, ARS, Washington DC.

Maxwell FG and Jennings PR. (Eds.). 1980. *Breeding Plants Resistant to Insects*. John Wiley & Sons. Wiley-Blackwell.

Roberto F. 2018. *Plant Breeding for Biotic and Abiotic Stress Tolerance*. Springer.

Russel GE. 1978. *Plant Breeding for Pest and Disease Resistance*. Butterworths.

Sakai A and Larcher W. 1987. *Frost Survival in Plants*. Springer-Verlag.

Singh BD. 2006. *Plant Breeding*. Kalyani Publishers, New Delhi.
Turener NC and Kramer PJ. 1980. *Adaptation of Plants to Water and High Temperature Stress*. John Wiley & Sons.
van der Plank JE. 1982. *Host-Pathogen Interactions in Plant Disease*. Academic Press.

I. Course Title : Germplasm Characterization and Evaluation
II. Course Code : GPB 517
III. Credit Hours : 2(1+1)

IV. Why this course ?

Students need to learn about morphological and quality agronomic traits of accessions as well as their reaction to biotic and abiotic stresses. This will increase the importance of the germplasm.

V. Aim of the course

Students will gain knowledge on germplasm characterisation, evaluation and documentation of information. Recording of morphological and agronomic traits, including quality, as well as those for resilience to biotic and abiotic stresses that will promote utilisation. Exposure to development of web based tools for systematic description for efficient use of germplasm.

VI. Theory

Unit I

Understanding genetic diversity in crop plants; Crop descriptors, descriptor states; germplasm characterization/ evaluation procedures; evaluation of germplasm for specific traits; Measuring diversity using agro-morphological data, statistical procedures to measure population genetic variation, markers and their use in PGR, evaluation of biotic and abiotic stresses, Principles and methods for formulating core and mini core collections and their validation, Web based tools for management of data.

Unit II

Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces, evaluation and maintenance of wild relatives of crop plants. Genetic enhancement, Use of CWRs genetic resources for crop improvement.

Unit III

High throughput phenotyping systems- imaging and image processing concepts for automated germplasm characterization (phenotyping) – evaluation for nutritional traits, resistance traits -Biochemical and molecular markers for characterization.

VII. Practical

- Field layout and experimental designs;
- Recording field data on germplasm evaluation in different agri-horticultural crops,
- post harvest handling;
- Evaluating quality traits, biochemical and phyto-chemical evaluation of crop germplasm, data processing;
- Documentation, analysis of diversity and cataloguing, data analysis, viability equations, sampling strategies, data documentation, cataloguing, biochemical analyses of samples.

VIII. Teaching methods
- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

To educate students about science of managing genetic resources including principles involved in maintaining genetic integrity during regeneration, germplasm characterization and evaluation.

X. Suggested Reading

Brown AHD, Clegg MT, Kahler AL, Weir BS (eds.) 1990. *Plant Population Genetics, Breeding, and Genetic Resources*, Sinauer Associates, USA.

Frankel R and Galun E 1977. *Pollination Mechanisms, Reproduction and Plant Breeding. Monographs on Theoretical and Applied Genetics*, Springer-Verlag, Berlin, Heidelberg.

Hayward MD, Bosemak NO and Romagosa I. 1993. *Plant Breeding: Principles and Practices*, Chapman & Hall.

Holden JHN and Williams JT 1984. *Crop genetic resources: conservation and evaluation*, IBPGR.

Puzone, L and Th. Hazekamp 1996. *Characterization and Documentation of Genetic Resources Utilizing Multimedia Database*. NBPGR, New Delhi.

Rana RS, Sapra RL, Agrawal RC and Gambhir R 1991. Plant Genetic Resources, *Documentation and Information Management*. NBPGR, New Delhi.

Stoskopf NC 1993. *Plant Breeding: Theory and Practice*, Westview Press.

Sundeep Kumar, *et al.* 2016. *Evaluation of 19,460 wheat accessions conserved in the Indian national genebank to identify new sources of resistance to rust and spot blotch diseases.* PloS One Vol 11, pages 0167702.

Tripathi K, Bhardwaj R, Bhalla S, Kaur V, Bansal R, Yadav R, Gangopadhyay KK, Kumar A and Chaudhury R. 2018. *Plant Genetic Resources Evaluation: Principles and Procedures*, Indian Council of Agricultural Research - National Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi. vi+50 p.

I. Course Title : Genetic enhancement for PGR Utilization

II. Course Code : GPB 518

III. Credit Hours : 2(1+1)

IV. Why this course ?

Pre-breeding is a vital step in the link between plant genetic resources conservation and its use; Hence, this course is designed to inculcate theoretical and practical know how to understand and use classical and advanced plant breeding methods for planning and execution of prebreeding programmes so that the PGR is put into effective use for food and agriculture.

V. Aim of the course

To teach theoretical and practical know how on CWRs reproductive behavior, acclimatization and adaptation for utilization in prebreeding programmes usig advanced tools.

VI. Theory

Unit I

Concepts of gene pools; Introduction, potential of pre-breeding. Role of crop wild relatives, semi exotics, creating and managing variation, basic concepts to set up a successful pre-breeding programme.

Unit II

Understanding crop adaptation, handling and maintenance of CWRs, synchronization of flowering, overcoming impediments to flowering through photoperiodic adjustments, role of other barriers to flowering, role of amphidiploids, semi exotics and other unadapted germplasm, identifying desirable traits in natural populations, screening for biotic and abiotic stress resistance traits; screening of nutritionally important traits, genetic analysis to understand the inheritance of novel traits.

Unit III

Parental selection for prebreeding, search for superior genotypes, breeding methods for trait transfer; moving the genes - unadapted to adapted, wide hybridization, Incongruity and its management, modern tools for incongruity management, cytogenetical approaches for gene transfer such as alien addition and substitution, segregating populations and their management in wide crosses, purging the undesirable traits, testing and improving the adaptability of wide cross derivatives, cytological studies, florescence microscopy, embryo rescue methods, pollen physiology and storage, pollen storage methods to facilitate wide hybridization, pre- and post-zygotic barriers.

VII. Practical

- Characterization of CWRs by visiting the fields;
- Screening methods for special traits-biotic and abiotic resistance;
- Screening for nutritional traits;
- Crossability studies in CWRs of cereals, legumes, oilseeds, vegetables. Assessment of pre and post-zygotic barriers in wide hybridization crosses;
- Pollen storage studies;
- Special requirements for growing CWRs, inducing flowering by manipulating day length, temperature, chemical spraying, etc.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

Students would be conversant with handling of unadapted germplasm, screening methods for special traits-biotic and abiotic resistance, nutritional traits, characterization of CWR, breeding, etc.

X. Suggested Reading

Andey Pereira. 2006. *Plant Reverse Genetics*, Methods and Protocols, Humana Press

Bisht *et al*. 2004. Broadening the genetic base of sesame (*Sesamum indicum* L.) through genetic enhancement. *Plant Genetic Resources* **2**(3): 143–151.

Dale JW and von Schantz M. 2007. *From genes to genomes. Concepts and applications of DNA technology*. John Wiley & Sons Ltd., Chichester, England.

Duvick DN. 1990. Genetic enhancement and plant breeding. p. 90–96. In: J. Janick and J.E. Simon (eds.), Advances in new crops. Timber Press, Portland.

Goodman, RM. 2004. *Encyclopedia of plant and crop science*. Marcel Dekker Inc., Switzerland.

Kimber, G and Feldman, M. 1987. *Wild Wheat: An introduction*. Special report 353, College of Agriculture, University of Missouri-Columbia.

Lynch M. and Walsh B. 1998. *Genetics and analysis of quantitative traits*. Sinauer Associates Inc., MA, USA.
Murphy D. 2007. *Plant breeding and biotechnology: Societal context and the future of agriculture*. Cambridge University Press, Cambridge, UK.
Ram JS. 2010. *Plant Cytogenetics*. CRC Press.
Ramanatha Rao V, Brown AHD, Jackson M. 2001. *Managing Plant Genetic Diversity*. CABI publication.
Sharma S, Upadhyaya HD, Varshney RK, *et al*. 2013. Pre-breeding for diversification of primary gene pool and genetic enhancement of grain legumes. *Front. Plant Sci*. **4**: 309.
Yunbi Xu. 2010. Molecular plant breeding, CABI publishers

e-Resources

https://www.integratedbreedPlaning.net/ pre-breeding-effective-use-plant-genetic-resources
http://www.croptrust.org/
http://www.bioversityinternational.org/training/training_materials/pre_breeding.htm
http://www.grdc.com.au/director/research/prebreeding

Course Title with Credit Load
Ph.D. in Genetics and Plant Breeding (GPB)

Course Code	Course Title	Credit
GPB 601*	Advances in Plant Breeding Systems	3(3+0)
GPB 602	Advances in Biometrical Genetics	3(2+1)
GPB 603	Molecular Cytogenetics for Crop Improvement	2(2+0)
GPB 604	Plant Genetics Resources, Conservation and Utilization	2(2+0)
GPB 605*	Genomics in Plant Breeding	3(3+0)
GPB 606	Population Genetics	2(2+0)
GPB 607	Crop Evolution	3(3+0)
GPB 608	Breeding Designer Crops	2(1+1)
GPB 609*	IPR and Regulatory Mechanism (e-course)	1(1+0)
	Major courses (Minimum 12 credits from above courses including *marked Courses)	12
	Minor courses	06
	Supporting courses	05
GPB 691	Seminar I	01
GPB 692	Seminar II	01
GPB 699	Thesis/ Research	75
	Total Credits	100

Comprehensive (Pre-qualifying) Examination (Non-credit of 100 marks) Satisfactory/ Not satisfactory

*Compulsory Major Courses

Course Contents
Ph.D. in Genetics and Plant Breeding (GPB)

I. Course Title : Advances in Plant Breeding Systems*
II. Course Code : GPB 601
III. Credit Hours : 3(3+0)

IV. Why this course?

This course is an advancement of principles, various plant breeding methodologies and procedures in the development of a complex population; MAS for selection of qualitative and quantitative traits, Gene pyramiding, marker-based utilization of exotic Germplasm and introgression libraries.

V. Aim of the course

To impart theoretical knowledge about advances in plant breeding.

VI. Theory

Unit I

Advances in reproductive biology of crops; Genes governing the whorls formation and various models proposed; Pollen pistil interaction: biochemical and molecular basis, environmental factors governing anthesis and bottlenecks for gene transfer.

Unit II

Plant Breeding methodologies: Classic versus modern; Over view of Pre and Post Mendelian breeding methods in self and cross pollinated crops; Molecular and transgenic breeding approaches; doubled haploid breeding, shuttle breeding, forward and reverse breeding, speed breeding, participatory plant breeding, breeding for organic situations.

Unit III

Principles and procedures in the formation of a complex population; Genetic basis of population improvement in crop plants; Recurrent selection methods in self and cross pollinated crops and their modifications; Convergent selection, divergent selection; Recurrent selection, usefulness in hybrid breeding programs; Reciprocal recurrent selection; Selection in clonally propagated crops – Assumptions and realities.

Unit IV

Choice of molecular markers for plant breeding efficiency, fingerprinting and genetic diversity assessment, application of MAS for selection of qualitative and quantitative traits; Gene pyramiding, accelerated backcrossing, marker-based utilization of exotic germplasm, introgression libraries.

Unit V

Genetic resources: primary, secondary, tertiary and alien trans gene pool; Molecular and biochemical basis of self-incompatibility and male sterility, nucleocytoplasmic interactions with special reference to male sterility – genetic, biochemical and molecular bases.

Unit VI

Genetic engineering technologies to create male sterility, prospects and problems, use of self-incompatibility and sterility in plant breeding – case studies; Fertility restoration in male sterile lines and restorer diversification programs; Conversion of agronomically ideal genotypes into male sterile: Concepts and breeding strategies; Case studies - Generating new cyto-nuclear interaction system for diversification of male sterile; Stability of male sterile lines – Environmental influence on sterility, Environmentally Induced Genic Male Sterility (EGMS) – Types of EGMS; Influence on their expression, genetic studies; Photo and thermo sensitive genetic male sterility and its use in heterosis breeding; Temperature sensitive genetic male sterility and its use heterosis breeding; Apomixis and its use in heterosis breeding; Incongruity: Factors influencing incongruity Methods to overcome incongruity mechanisms.

Unit VII

Breeding for climate change -Improving root systems, abiotic stress tolerance, water use efficiency, flooding and sub-mergence tolerance; Biotic stress tolerance; Nutrient use efficiency, nitrogen fixation and assimilation, greenhouse gases and carbon sequestration; Breeding for bio-fortification.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After completion of this course the student will be able to know variousplant breeding methodologies, principles and procedures for the formation of a complex population; MAS for selection of qualitative and quantitative traits, Gene pyramiding, marker based utilization of exotic Germplasm and Breeding for climate change

IX. Suggested Reading

Agarwal RL. 1996. *Fundamentals of Plant Breeding and Hybrid Seed Production*. Oxford & IBH.

Allard RW. 1966. *Principles of Plant Breeding*. John Wiley & Sons.

Briggs FN and Knowles PF. 1967. *Introduction to Plant Breeding*. Reinhold.

Fehr WR. 1987. *Principles of Cultivar Development: Theory and Technique*. Vol I. Macmillan.

Hayes HK, Immer FR and Smith DC. 1955. *Methods of Plant Breeding*. McGraw-Hill.

Kang MS and Priyadarshan PM (Edit.). 2007. *Breeding Major Food Staples*. Blackwell Publishing.

Kole C. 2013. *Genomics and Breeding for Climate-Resilient Crops*. Springer. Volume 2-Target Traits.

Mandal AK, Ganguli PK and Banerji SP. 1995. *Advances in Plant Breeding*. Vol. I, II. CBS.

Richards AJ. 1986. *Plant Breeding Systems*. George Allen & Unwin.

Sharma JR. 1994. *Principles and Practice of Plant Breeding*. Tata McGraw-Hill.

Simmonds NW. 1979. *Principles of Crop Improvement*. Longman.

Singh BD. 1997. *Plant Breeding: Principles and Methods*. 5th Ed., Kalyani Publishers, New Delhi.

Singh P. 1996. *Essentials of Plant Breeding*. Kalyani Publishers, New Delhi.

Welsh JR. 1981. *Fundamentals of Plant Genetic and Breeding*. John Wiley.

I. Course Title : Advances in Biometrical Genetics

II. Course Code : GPB 602

III. Credit Hours : 3(2+1)

IV. Why this course?

This course is essential to understand various qualitative, quantitative systems/ techniques related to genetic improvement of crops, G x E Interaction, Construction of saturated linkage maps and Marker Assisted Selection (MAS).

V. Aim of the course

To impart theoretical knowledge and computation methods for non-allelic interactions, mating designs and component analysis and their significance in plant breeding.

VI. Theory

Unit I

Continuous variation-evolutionary studies; Genetic principles of continuous variation, Qualitative and quantitative techniques-differences, population types, approaches; various types of metrics, F_2, $F\alpha$ and mixed; Selection of parents Simultaneous selection models; Use of Multiple regression analysis in selection of genotypes.

Unit II

Components of mean- Additive effect, breeding value, coefficient of gene dispersion, dominance; Simple scaling test, expectation of mean of character in various types of families in coupling and dispersed phase; Epistasis- Specification, weighted and un-weighted joint scaling test; Effect of linkage to generation mean, specification of mean to G × E interaction.

Unit III

Component of variances-advantages, variances of different generations, balance sheet of variance; estimation of parameters-weighted and unweighted, least square analysis; random mating population; experimental population-BIPs, NCD-I, II, III, Triple test cross for random mating population and inbreds; Estimates of linkage and non-allelic interactions; Combining ability analysis, Hayman's Approach.

Unit IV

G × E Interaction, stability and adaptability; Advanced models in stability analysis - Pattern analysis - Additive Main Effect and Multiplicative Interaction (AMMI) analysis and other related models; Merits and limitation of different stability analysis methods; Analysis and selection of genotypes; Methods and steps to select the best model - Biplots and mapping genotypes.

Unit V

Construction of saturated linkage maps, concept of framework map development; QTLs-different types of markers and mapping populations, linkage maps, mapping-Strategies for QTL mapping - desired populations, statistical methods; MAGIC populations, Marker Assisted Selection (MAS) - Approaches to apply MAS in Plant breeding - selection based on markers - simultaneous selection based on marker and phenotype - Factors influencing MAS; Heritability of the trait, proportion of genetic variance, linkage disequilibrium between markers and traits and selection methods; Use of advanced software packages for biometrical analysis, interpretation of analysed data.

VII. Practical

- Generation mean analysis: ABC scaling test and Joint scaling test- Analysis and interpretation;
- Estimation of variance of different filial generations and interpretations;
- Diallel analysis: Numerical, graphical and combining ability analysis; Triallel analysis;
- NC Designs: Triple test cross analysis;
- Stability analysis: Eberhart and Russel model;
- AMMI model - Principal Component Analysis model - Additive and multiplicative model - Shifted multiplicative model - Analysis and selection of genotypes - Methods and steps to select the best model - Selection systems - Biplots and mapping genotypes;
- Construction of linkage maps and QTL mapping - Strategies for QTL mapping; statistical methods in QTL mapping;
- Phenotype and Marker linkage studies;
- Use of advanced software in biometrical analysis.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After the completion of this course student will be able to understand various Qualitative and quantitative techniques, G x E Interaction, Construction of saturated linkage maps and Marker Assisted Selection, Use of advanced software packages for biometrical analysis, interpretation of analysed data.

X. Suggested Reading

Bos I and Caligari P. 1995. *Selection Methods in Plant Breeding*. Chapman & Hall.

Dabholkar AR.1993. *Elements of Biometrical Genetics.* Concept Publishing Co. New Delhi.

Falconer DS and Mackay J. 1996. *Introduction to Quantitative Genetics* (4 Ed.). ELBS/ Longman, London.

Mather K and Jinks JL. 1985. *Biometrical Genetics* (3rd Ed.). Chapman and Hall, London.

Nandarajan N and Gunasekaran M. 2008. *Quantitative Genetics and Biometrical Techniques in Plant Breeding.* Kalyani Publishers, New Delhi.

Roy D. 2000. *Plant Breeding, Analysis and Exploitation of Variation.* Narosa Publishing House, New Delhi.

Singh P and Narayanan SS. 1993. *Biometrical Techniques in Plant Breeding.* Kalyani Publishers, New Delhi.

Singh RK and Choudhary BD. 1987. *Biometrical Methods in Quantitative Genetics*. Kalyani Publishers, New Delhi.

Weir DS. 1990. *Genetic Data Analysis. Methods for Discrete Population Genetic Dat*a. Sinauer Associates.

Wricke G and Weber WE. 1986. *Quantitative Genetics and Selection in Plant Breeding*. Walter de Gruyter.

I. Course Title : Molecular Cytogenetics for Crop Improvement

II. Course Code : GPB 603

III. Credit Hours : 2(2+0)

IV. Why this course?

This course is needed to understand organization and structure of genome, karyotyping, Pre-breeding and applications of cytogenetically methods for crop improvement

V. Aim of the course

This course focuses on applications of cytogenetic techniques for crop improvement.

VI. Theory

Unit I

Organization and structure of genome, Genome size, Organization of organellar genomes, Nuclear DNA organization, Nuclear and Cytoplasmic genome interactions and signal transduction; Inheritance and expression of organellar DNA; Variation in DNA content - C value paradox; Sequence complexity – Introns and Exons, Repetitive sequences, Role of repetitive sequence.

Unit II

Karyotyping – Chromosome banding and chromosome painting; Tracking introgressions using FISH, GISH, localization and mapping of genes/ genomic segments.

Unit III

Pre-breeding and applications of cytogenetical methods for crop improvement; Location and mapping of genes on chromosomes: deficiency method; Interchange genetic consequence, identification of chromosomes involved and gene location; balanced lethal systems, their maintenance and utility; Multiple interchanges-use in producing inbreds, transfer of genes- linked marker methods; Duplication - production and use; Inversions and location of genes; B/ A chromosome translocations and gene location.

Unit IV

Trisomics- types, production, breeding behavior and location of genes, use of balanced tertiary trisomics in hybrid seed production; Monosomics methods of production, breeding behavior and location of genes; Intervarietal substitutions-allelic and non-allelic interactions; Telocentric method of mapping.

Unit V

Cytogenomics: Concept, tools and techniques for crop improvement; Chromosome sorting: Isolation of specific chromosome for development of molecular maps and gene location.

Unit VI

Role of polyploidy in crop evolution and breeding. Auto- and allopolyploids; Distant hybridization, barriers to interspecific and intergeneric hybridization; Behaviour of interspecific and intergeneric crosses.

VII. Teaching methods

- Power point presentation
- Chalk and Board

- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning Outcome

After the completion of this course the student will be able to understand Organization and structure of genome, karyotyping, Pre-breeding, polyploidy and applications of cytogenetically methods for crop improvement.

IX. Suggested Reading

Clark MS and Wall WJ. 1996. *Chromosomes: The Complex Code*. Chapman & Hall. 30 June 1996

Conger BV. (Ed.). 1981. *Cloning Agricultural Plants via in-vitro Techniques*. CRC Press. 31 January 2018

Constabel F and Vasil IK. (Eds.). 1988. *Cell Culture and Somatic Cell Genetics of Plants*. Vol. V. Cell Culture and Phytochemicals in Plant Cell Cultures. Academic Press.

Gupta P K. 2006. *Cytogenetics*. Rastogi Publisher

Lal R and Lal S. (Eds.). 1990. *Crop Improvement Utilizing Biotechnology*. CRC Press.

Mantel SH and Smith H. 1983. *Plant Biotechnology*. Cambridge University Press.

Sen SK and Giles KL. (Eds.). 1983. *Plant Cell Culture in Crop Improvement*. Plenum Press. 13 July 2013

Yao-Shan F. 2002. *Molecular Cytogenetics: Protocols and Application*. Human Press

I. Course Title : Plant Genetic Resources, Conservation and Utilization

II. Course Code : GPB 604

III. Credit Hours : 2(2+0)

IV. Why this course?

This course is needed to make the student aware about the importance of Plant Genetic Resources its Conservation and Utilization in crop improvement.

V. Aim of the course

To impart knowledge on the methods of germplasm conservation and its utilization

VI. Theory

Unit I

Concept of natural reserves and natural gene banks; *In situ* conservation of wild species in nature reserves: *in situ* conservation components, factors influencing conservation value, national plan for *in situ* conservation; *in situ* conservation of agro-biodiversity on-farm; scientific basis of *in situ* conservation on-farm, building on-farm conservation initiatives, implementation of on-farm conservation, management of *in situ* conserved genetic diversity on-farm, enhancing benefits for farmers from local crop diversity.

Unit II

Ex situ conservation: components, plant genetic resources conservation in gene banks, national gene banks, gene repositories, preservation of genetic materials under natural conditions, perma-frost conservation, guidelines for seed multiplication and exchange to network of active/ working collections, orthodox, recalcitrant seeds- differences in handling, clonal repositories, genetic stability under long term storage condition.

Unit III

In-vitro storage, maintenance of *in-vitro* culture under different conditions, *in-vitro* bank maintenance for temperate and tropical fruit crop species, spices, tubers, bulbous crops, medicinal and endangered plant species, conservation of embryos and ovules, cell/ suspension cultures, protoplast and callus cultures, pollen culture, micropropagation techniques, problems, prospects of *in-vitro* gene bank.

Unit IV

Cryopreservation- procedure for handling seeds of orthodox and recalcitrant-cryo-protectants, desiccation, rapid freezing, slow freezing, vitrification techniques, encapsulation/ dehydration techniques, national facilities, achievements, application of cryopreservation in agricultural, horticultural and forestry crops. Problems and prospects; challenges ahead.

Unit V

Concept and procedure for PGR management, germplasm characterization, evaluation and utilization; Concept of core and mini core; collections and registration of plant germplasm.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion of this course the student will be able to know about the various techniques of conservation of Plant Genetic Resources and its Utilization in crop improvement.

IX. Suggested Reading

Ellis RH, Roberts EH and White Head J. 1980. *A New More Economic and Accurate Approach to Monitor the Viability of Accessions During Storage in Seed Banks*. FAO/ IBPGR Pl. Genet. Resources News 41-3-18.

Frankel OH and Hawkes JG. 1975. *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press, Cambridge.

Paroda RS and Arora RK.1991. *Plant Genetic resource Conservation and management*, NBPGR, New-Delhi.

Simmonds NW. 1979. *Principles of Crop Improvement,* Longman.

Westwood MN. 1986. *Operation Manual for National Clonal Germplasm Repository*. Processed Report. USDA-ARS and Oregon State Univ. Oregon, USA.

Withers LA. 1980. *Tissue Culture Storage for Genetic Conservation*. IBPGR Tech. Rep. IBPGR, Rome, Italy.

I. Course Title : Genomics in Plant Breeding*

II. Course Code : GPB 605

III. Credit Hours : 3(3+0)

IV. Why this course?

The knowledge of recent trends in plant genomics, genome sequencing, molecular maps, and concepts of high-throughput proteomics, metabolomics and phenomics is essential in rapid crop improvement programmes.

V. Aim of the course

To impart practical skills in advanced molecular techniques in genome mapping structural/ functional genomics.

VI. Theory

Unit I

Introduction to the plant genomes: nuclear, chloroplast and mitochondrial genomes; Concept of genome size and complexity: C-value paradox, repetitive and unique DNA.

Unit II

Genome sequencing: Principles and techniques of conventional approaches and next generation sequencing including sequencing-by-synthesis/ ligation and single molecule real time (SMRT) technologies; Applications of sequence information: structural, functional and comparative genomics; Plant genome projects: Strategies for genome sequencing including shot gun and clone-by-clone method.

Unit III

Molecular maps: Use of molecular markers/ SNPs for development of genetic and physical maps; Linkage and LD-based gene mapping approaches including gene/ QTL mapping, genome wide association studies (GWAS) and association analysis; Integration of genetic and physical map for map-based cloning of economically important genes. Concept of allele mining; Diversity array technology: concepts and applications.

Unit IV

Functional genomics: concept of reverse and forward genetics; Use of activation tagging, transposon tagging, insertional mutagenesis, TILLING and ecoTILLING for crop improvement; Genome-wide and gene-specific transcriptomics approaches: serial analysis of gene expression, massively parallel signature sequencing, next generation sequencing, microarray, northern hybridization, RT-PCR, qRT-PCR and molecular beacon.

Unit V

Development and management of database; Applications of bioinformatics tools/ software in genomics for crop improvement. Basic concepts of high-throughput proteomics, metabolomics and phenomics.

Unit VI

Recent transgene free genome editing tools such as CRISPR-Cas9 system, TALENS and ZFNs for crop improvement. Cisgenesis and Intragenesis tools as twin sisters for Crop Improvement; Genomics-based plant breeding: Genome-Wide Genetic Diversity Studies, Identification of molecular markers linked to single Genes and QTL, Marker Assisted Selection (Marker Assisted Backcross Selection, Association mapping, Breeding by Design, Genome selection).

VII. Teaching methods

- Power point presentation
- Chalk and Board

- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion ofthis course, the student will have expertise on about different techniques for genome sequencing, molecular maps, and concepts of high-throughput proteomics, metabolomics and phenomics in crop improvement

IX. Suggested Reading

Alonso JM, Stepanova AN. 2015. *Plant Functional Genomics: Methods and Protocols*. Springer.

Chopra VL, Sharma RP, Bhat SR and Prasanna BM. 2007. *Search for New Genes*. Academic Foundation, New Delhi.

Hackett PB, Fuchs JA and Messing JW. 1988. *An Introduction to Recombinant DNA Technology—Basic Experiments in Gene and Manipulation*. 2nd Ed. Benjamin Publication Co.

Primose SB and Twyman RM. 2006. *Principles of Gene Manipulation and Genomics*. 7th Ed. Wiley-Blackwell Publishing.

Sambrook J and Russel D. 2001. *Molecular Cloning - a Laboratory Manual*. 3rd Ed. Cold Spring Harbor Laboratory Press.

Singh BD. 2005. *Biotechnology: Expanding Horizons*. Kalyani Publishers, New Delhi.

Somers DJ, Langridge P, Gustafson JP. 2009. *Plant Genomics: Methods and Protocols*. Springer.

e-Resources

http://gramene.org
https://www.arabidopsis.org
https://wheat.pw.usda.gov
http://ncbi.nlm.nih.gov
http://www.maizegenetics.net

I. Course Title : Population Genetics

II. Course Code : GPB 606

III. Credit Hours : 2(2+0)

IV. Why this course?

Population improvement programmes are the basis of genetic enhancement in cross pollinated crops. This course is needed to make the students aware about the population genetics and its role in crop improvement.

V. Aim of the course

To impart knowledge on structure, properties and their breeding values of different population.

VI. Theory

Unit I

Population: Properties of population, Mendelian population; Genetic constitution of a population through time, space, age structure, etc.; Frequencies of genes and genotypes; Causes of change: population size, differences in fertility and viability, migration and mutation.

Unit II

Hardy-Weinberg equilibrium, Hardy-Weinberg law, Proof and applications of the Hardy-Weinberg law, Test of Hardy-Weinberg equilibrium; Mating frequencies:

Non-dominance, Codominance, Snyder's ratio, importance and its effect over random mating in succeeding generations.

Unit III

Multiple alleles, More than one locus, Sex linked genes; Use of gene and genotypic frequencies evaluation in field population level; Interpretations - Changes of gene frequency, Migration, Mutation, Recurrent and non-recurrent Selection; Balance between selection and mutation; Selection favoring heterozygotes; Overdominance for fitness.

Unit IV

Mating systems, Random mating population, Nonrandom mating: selfing –inbreeding coefficient, panmictic index, sibmating, Assortative mating and disassortative mating; Pedigree populations and close inbreeding, Estimation of linkage disequilibrium, Correlation between relatives and estimation of F; Effect of inbreeding and sibbing in cross pollinated crops; Gene substitution and average effects; Breeding value- Genetic drift; Genetic slippage, Co-adapted gene complexes; Homoeostasis- Adaptive organization of gene pools; Polymorphism- Balanced and Non-balanced polymorphism, heterozygous advantage- Survival of recessive and deleterious alleles in populations.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion of this course the student will be well versed with population genetics, its components and applications in crop improvement.

IX. Suggested Reading

Chawla V and Yadava RK. 2006. *Principles of Population Genetics – A Practical Manual*. Dept. of Genetics, CCS HAU Hisar.

Falconer DS and Mackay J. 1996. *Introduction to Quantitative Genetics*. Longman.

Jain JP, Jain J and Parbhakaran VT. 1992. *Genetics of Populations*. South Asia Books.

Li CC. 1955. *Population Genetics*. The Univ. of Chicago Press.

Mather K and Jinks JL. 1982. *Biometrical Genetics*. Chapman & Hall.

Sorrens D and Doniel G. 2007. *Methods in Quantitative Genetics*. Series: *Statistics for Biology and Health*. Likelihood.

Tomar SS. 1992. *Text Book of Population Genetics*. Universal Publication.

I. Course Title : Crop Evolution

II. Course Code : GPB 607

III. Credit Hours : 3(3+0)

IV. Why this course?

This course imparts knowledge about the origin and evolution of species, centres of diversity, speciation, domestication and significance of polyploidy.

V. Aim of the course

To impart knowledge on crop evolutionary aspects and role of mutations, hybridizations and polyploidy in crop evolution and improvement.

VI. Theory

Unit I

Origin and evolution of species; Centres of diversity/ origin, diffused centres; Time and place of domestication; Patterns of evolution and domestication-examples and Case studies; Domestication and uniformity – Characteristics of early domestication and changes – Concept of gene pools and crop evolution; Selection and Genetic drift – Consequences.

Unit II

Speciation and domestication–The process of speciation, Reproductive isolation barriers; Genetic differentiation during speciation; Hybridization - speciation and extinction; Exploitation of natural variation: Early attempts to increase variation, Distant hybridization and introgression, Inter-specific, inter-generic hybridization, scope and limitations, techniques to overcome the limitations; Gene transfer into cultivated species, tools and techniques; Validation of transferred genes and their expression; Controlled introgressions.

Unit III

Processes in crop evolution and stabilization of polyploids, cytogenetic and genetic stabilization; Genome organization – Transgenesis in crop evolution, Multifactorial genome, Intragenomic interaction, Intergenomic interaction, Genome introgression; Methods to study crop evolution - Contemporary Methods, Based on morphological features, Cytogenetic analysis, Allozyme variations and crop evolution, DNA markers, genome analysis and comparative genomics.

Unit IV

Evolutionary significance of polyploidy, evolution of crop plants through ploidy manipulations; Polyploids: methods, use of autopolyploids; haploidy and DH-method of production and use, allopolyploids; synthesis of new crops; Case studies – Cereals, Pulses, Oilseeds, vegetables, Fibre crops, Plantation crops, Forage crops, Tuber crops, Medicinal Plants.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion of this course the student will have knowledge of Origin and evolution of species, Centres of diversity, Speciation, domestication and significance of micro-mutations and polyploidy in genetic improvement of crop plants.

IX. Suggested Reading

Hancock JF. 2004. *Plant Evolution and the Origin of Crop Species*. 2nd Ed. CABI.

Ladizinsky G. 1999. *Evolution and Domestication*. Springer.

Miller AJ. 2007. *Crop Plants: Evolution*. John Wiley & Sons.
Smartt J and Simmonds NW. 1995. *Evolution of Crop Plants*. Blackwell.

I. Course Title : Breeding Designer Crops
II. Course Code : GPB 608
III. Credit Hours : 2(1+1)

IV. Why this course?

This course enlightens about developing varieties for special traits, physiological efficiency and nutritional enhancement. It gives concept of biopharming and development of varieties producing targeted compounds, nutraceuticals and industrial products.

V. Aim of the course

Breeding crops for higher physiological efficiency and nutritional enhancement.

VI. Theory

Unit I

Breeding of crop ideotypes; Genetic manipulations through recombination breeding, genomics and transgenics for physiological efficiency, nutritional enhancement, special compounds-proteins, vaccines, gums, starch and fats.

Unit II

Physiological efficiency as a concept, parametric and whole plant physiology in integrated mode; Physiological mechanism of improvement in nutrient use efficiency, water use efficiency, osmotic adjustment, photosynthetic efficiency, stay green trait and its significance in crop improvement; Breeding for special traits, viz., oil, protein, vitamins, amino acids, etc.; Ecospecific ideotypes, Ideotypes for high and low moisture conditions, low and high input conditions, conversion mechanism of C_3 to C_4 plants; Determination of genetics of above mentioned traits.

Unit III

Improvement in yield potential under sub-optimal conditions by manipulating source and sink, canopy architecture, plant-water relationships, effect of suboptimal conditions on cardinal plant growth and development processes, enhancing input use efficiency through genetic manipulations.

Unit IV

Concept of biopharming and development of varieties producing targeted compounds, nutraceuticals and industrial products; Success stories in vaccines, modified sugars, gums and starch through biopharming.

Unit V

Biosafety management, segregation and isolation requirements in designer crop production and post-harvest management.

VII. Practical

- Demonstration of plant responses to stresses through recent techniques;
- Water use efficiency, transpiration efficiency, screening techniques under stress conditions such as electrolyte leakage, TTC, chlorophyll fluorescence, canopy temperature depression, stomatal conductance, chlorophyll estimation, heat/ drought/ salt shock proteins.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome:

Pass outs will have clear understanding of ideotypes of crops under varied agro-climatic situations and breed for physiological efficient genotype. Can develop varieties for special traits having high therapeutic and nutracetrical value.

X. Suggested Reading

Balint A. 1984. *Physiological Genetics of Agricultural Crops*. AK Ademiaikiado.
Hay RK. 2006. *Physiology of Crop Yield*. 2nd Ed. Blackwell.
Pessarakli M. 1995. *Handbook of Plant and Crop Physiology*. Marcel Dekker.
Taiz L and Zeiger E. 2006. *Plant Physiology*. 4th Ed. Sinauer Associates.

I. Course Title : IPR and Regulatory Mechanism (e-course)*
II. Course Code : GPB 609
III. Credit Hours : 1(1+0)

IV. Why this course?

Biodiversity conservation and its judicious utilization are important in sustainable plant breeding programs. Breeders' and farmers' rights are important in scenario of globalization of agriculture so knowledge of IPRs is essential for a plant breeder to protect his varieties.

V. Aim of the course

The main objective of this course is to equip students and stakeholders with knowledge of intellectual property rights (IPR), related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

VI. Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement

VII. Teaching methods

- Power point presentation
- Smart board

- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

The students will have acquaintance of intellectual property rights, national and international laws on biodiversity and sustainable use of plant genetic resources through transfer and sharing. Can assist in follow up of various treatises and laws for research collaborations at international levels.

IX. Suggested Reading

Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.

Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.

Intellectual Property Rights: Key to New Wealth Generation. 2001. NRDC & Aesthetic Technologies.

Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. *Technology Generation and IPR Issues*. Academic Foundation.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Sciences
– Seed Science and Technology

Preamble

(Seed Science and Technology)

The proposed curriculum of Seed Science and Technology discipline is designed with the view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. In the present state, students aspire for overseas admissions for education and employment, or even in India they seek placements in seed corporations and multinational seed companies. In order to facilitate easier transitions for post-graduate degree courses and job prospects overseas, there is a need to upgrade the post-graduate syllabus to international standards. Therefore, the present syllabus needs revision so as to prepare the students to cope with current professional scenario with relevance to practical needs and skill requirements. The BSMA (Plant Sciences) committee examined the existing syllabus of Seed Science and Technology and analysed carefully in terms of content, relevance, quality and pattern and then synthesized the present proposed syllabus.

By intensive discussion with the core faculty, experts and based on the feedback from seed industry professionals, the entire syllabus was restructured with the improvement in existing courses as well as addition of new courses. The syllabus was suitably finalized with the view to equip the students to gain knowledge and skills sets and to prepare themselves for global competiveness to meet out their goals.

Seed quality is vital for sustainable crop production and food security. Seed enhancement includes physical, physiological and biological treatments to overcome germination constraints, to maintain uniform plant stands, earlier crop development and better yields. Seed enhancement techniques are designed in such a way to reduce emergence time of seed by earlier start of metabolic activities and resource mobilization for better emergence and seedling vigour. The knowledge of molecular pathways elucidating mode of action of priming agents, reduced longevity of primed seeds, efficiency of physical and biological agents for seed treatments and market availability of high-quality seeds are some of the challenges for scientists and seed industry.

Seed dormancy allows seeds to overcome periods that are unfavourable for seedling establishment and significant role in adaptation and evolution of seed plants, and therefore it is important for plant ecology and agriculture. Seed ecology is the study of ecological strategies by which plants ensure their reproduction by seed. Understanding the dynamics of seed bank, environmental conditions that impose dormancy and induce germination, and factors that influence successful seedling establishment is utmost important. The knowledge on seed dormancy and seed ecology will enhance the effectiveness in planning for control of weeds, successful propagation of native economically important trees, shrubs, vines and grasses, and also reclamation of damaged agro-ecosystems.

Organic seed system when viewed as an alternative to the dominant seed system helps to address the bigger problems in agriculture. Expanding organic seed systems can also increase economic opportunities for farmers who successfully produce organic seed in their farm. Knowledge on the practices of organic seed production, certification and distribution will focus our production system towards the present day needs for quality life.

Seed provides the genetic tools to confront these day-to-day challenges in the field, and breeding plants in the environment of their intended use. Seed Science and Technology therefore represents profound potential for improving our food and agricultural production systems. Hence, the holistic and comprehensive knowledge on these areas of Seed Science and Technology should be taught to the students to make them more efficient in scientific research and also to contribute in building vibrant seed industry. Considering the importance and present requirement in the field of seed science, the proposed syllabus is formulated in such a way that it will enhance the knowledge and skill sets of students.

The existing courses, viz., Seed dormancy and germination, Seed quality testing and enhancement, Seed technology of tree species, Seed industry and marketing management and Seed planning trade and marketing have been completely revised and upgraded. Some new courses, viz., Organic seed production, Physiology and biochemistry of seeds, Seed vigour and crop productivity, Advances in seed quality enhancement and Seed ecology have also been included in the proposed syllabus for post-graduate degree programmes.

Course Title with Credit load
M.Sc. (Ag) in Seed Science and Technology (SST)

Course Code	Course Title	Credit Hours
SST 501*	Seed Developmental Biology	2 (1+1)
SST 502	Seed Dormancy and Germination	2 (1+1)
SST 503*	Seed Production Principles and Techniques in Field Crops	3 (2+1)
SST 504*	Seed Production Principles and Techniques in Vegetable Crops	3 (2+1)
SST 505	Seed Production Techniques in Fruits, Flowers, Spices, Plantation and Medicinal Crops	3 (2+1)
SST 506	Seed Production Techniques in Forage, Pasture and Green Manure Crops	2 (1+1)
SST 507*	Seed Legislation and Certification	3 (2+1)
SST 508*	Post Harvest Handling and Storage of Seeds	3 (2+1)
SST 509*	Seed Quality Testing and Enhancement	2 (1+1)
SST 510	Seed Technology of Tree Species	2 (1+1)
SST 511	Seed Industry and Marketing Management	2 (1+1)
SST 512	Seed Health Testing and Management	2 (1+1)
	Major Courses (minimum 20 credits from above courses including *marked Courses)	20
	Minor Courses	08
	Supporting Courses	06
	Common Courses	05
SST 591	Seminar	01
SST 599	Research	30
	Total Credits	**70**

*Compulsory Major Courses

Course Contents
M.Sc. (Ag) in Seed Science and Technology (SST)

I. Course Title : Seed Developmental Biology*
II. Course Code : SST 501
III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed is the most complex and successful unit of reproduction in flowering plants. Seed contains genetic wisdom of the past and act as an agent of genetic transfer from generation to generation. Basic knowledge on seed developmental biology will enable the learners to understand the structure of seed to take up research in seed science and technology.

V. Aim of the course

To acquire knowledge on development and maturation of essential structures of seed and their influence on seed quality.

VI. Theory

Unit I

Floral biology – types of pollination, mechanisms; sporogenesis – micro and mega sporogenesis; gametogenesis – development of male and female gametes and their structures; pollination and fertilization – mode of pollination, double fertilization, factors affecting pollination, fertilization; self-incompatibility and male sterility.

Unit II

Embryogenesis – development of monocot and dicot embryos – embryo plane formation – development of endosperm, cotyledons and seed coat – hard seed; apomixis – identification, classification, significance and its utilization; poly-embryony – types and significance; haplontic and diplontic sterility system, causes of embryo abortion, embryo rescue technique; somatic embryogenesis.

Unit III

Seed development – source of assimilates – mechanism of translocation; chemical composition – synthesis and deposition of storage reserves – starch, protein, fat and secondary metabolites – hormonal regulation.

Unit IV

Maturation drying – orthodox and recalcitrant seeds – desiccation tolerance – mechanism – structural changes during desiccation – role of LEA protein.

Unit V

Seed maturity indices – physiological and harvestable maturity; biotic and abiotic factors influencing seed development – development of hard seeds.

VII. Practical

- Study on floral biology of monocot;
- Study on floral biology of dicot plants;

- Study on pollen morphology of different crops;
- Pollen germination and viability test in major crops;
- Seed embryo and endosperm development in monocots;
- Seed embryo and cotyledon development in dicots;
- Anatomy and morphology of seed coat during development;
- Hard seed coat development;
- Study on external and internal structures;
- Seed development and maturation in agricultural crops – physical and physiological changes;
- Seed development and maturation in horticultural crops – physical and physiological changes;
- Study of biochemical changes during seed development and maturation in agricultural crops;
- Study of biochemical changes during seed development and maturation in horticultural crops;
- Study on physiological and harvestable maturity and maturity indices in different crops;
- Study on acquisition of seed dormancy and germination at different stages of maturity;
- Preparation of seed album and identification of seeds.

VIII. Teaching methods

- Classroom lectures
- Slide shows
- Student assignments and presentation
- Group tasks
- Field and laboratory experiments
- Field visits

IX. Learning outcome

Successful completion of this course enable student to take up advanced research on seed developmental biology and understanding on fundamental aspects of gametogenesis, seed development and maturity.

X. Suggested Reading

Adkins SW, Ashmore SE and Navi SC. 2007. *Seeds: Biology, Development and Ecology*. CAB International, Oxfordshire, UK.

Bewley JD and Black M. 1994. *Seeds: Physiology of Development and Germination*. Springer, New York.

Bewley JD, Bradford KJ, Hilhorst HWM and Nanogaki H. 2013. *Seeds: Physiology of Development, Germination and Dormancy*. Springer, New York.

Black M, Bewley JD and Halmer P. 2006. *The Encyclopedia of Seeds: Science, Technology and Uses*. CAB International publications, UK.

Chhabra AK. 2006. *Practical Manual of Floral Biology of Crop Plants*. Department of Plant Breeding, CCSHAU, Hisar.

Copeland, LO and McDonald MB. 2001. *Principles of Seed Science and Technology*. 4th Ed. Kluwer Academic publishers, USA.

Frankel R and Galun E. 1977. *Pollination Mechanisms, Reproduction and Plant Breeding*. Springer Verlag, New York.

Hesse MH, Haidemarie R, Zettler M, Webber R, Buchner AR, Radivo and Ulrich S. 2009. *Pollen Terminology. An illustrated hand book*. Springer Verlag, New York.

Kozlowski. TT. 2012. *Seed Biology: Importance, Development and Germination*. (Vol. I). Academic Press Inc., New York.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, Rajasthan.

XI. Suggested e-books

https://www.springer.com/in/book/9783642810619
https://www.springer.com/in/book/9780792373223
https://www.springer.com/gp/book/9780792346456
https://www.cabi.org/bookshop/book/9780851997230
https://www.worldcat.org/title/seed-development-and-germination/oclc/44954614
https://books.google.co.in/books/about/Seeds.html?id=-Zbzr1F_z74C&redir_esc
https://books.google.co.in/books/about/Seeds.html?id=6S75BwAAQBAJ& printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false

XII. Suggested websites

https://agriinfo.in/botany/18/
http://www.seedbiology.de/structure.asp
http://www.fao.org/3/ad232e/AD232E02.htm
sbc.ucdavis.edu/Research_pages/Seed_physiology_and_technology/
https://courses.lumenlearning.com/wm-biology2/chapter/development-seeds-fruit
www.iari.res.in/index.php?option=com_content&view=article&id=449& Itemid=137

I. Course Title : Seed Dormancy and Germination
II. Course Code : SST 502
III. Credit Hours : 2 (1+1)

IV. Why this course?

Physiology and bio chemistry of dormancy and germination is basic science in the field of Seed Science and Technology. Complete understanding on the mechanisms of acquisition and release of dormancy and germination enable the students to take up research on advanced aspect which may helpful to design the seed for our requirement.

V. Aim of the course

To impart knowledge on significance, mechanism of dormancy, induction and release of seed dormancy and germination, types and factors influencing germination and their management.

VI. Theory

Unit I

Seed dormancy – definition, concept and theories – significance – evolution; classification and mechanism of dormancy – ecological singnificance.

Unit II

Induction of dormancy during development – hormonal, physiological, molecular and genetic control of dormancy – maternal and paternal contribution; environmental factors influencing dormancy induction and release – seasonal influence – winter and summer annuals – secondary dormancy induction mechanism; artificial induction of dormancy and release; soil seed bank – natural release of dormancy and its mechanism; dormancy breaking – principles and methods.

Unit III

Seed germination – types and phases of germination; imbibition – pattern and water kinetics – events of germination – physical, physiological, biochemical changes -aerobic and anaerobic respiration quiescent.

Unit IV – Physiological and biochemical changes

Enzyme activation – mechanism – factors affecting enzyme activation – breakdown of stored materials – starch, protein and fat – energy generation – mobilization of storage reserves – changes in phenolic compounds.

Unit V – Molecular and genetic mechanisms

Molecular and genetic control of seed germination – auto tropism; factors affecting germination – media – temperature – light – gases; *in-situ* and viviparous germination – causes and mechanism – pattern of seed germination – tri-phasic curve.

VII. Practical

- Seed dormancy – identification of dormancy;
- Estimation of ABA and GA in dormant and non-dormant seeds;
- Study on artificial induction of dormancy;
- Dormancy breaking methods – scarification and stratification;
- Dormancy breaking methods – hormonal and chemical treatments;
- Dormancy breaking methods – after ripening and leaching of inhibitors;
- Dormancy breaking methods – combined treatments;
- Assessing the period of natural release of seed dormancy;
- Seed germination – studying the pattern of imbibition;
- Studying the pattern of seed germination in different media;
- Study on influence of light and temperature on germination and seedling development;
- Estimation of hydrolytic enzyme – α amylase in different species;
- Estimation of hydrolytic enzyme – protease;
- Estimation of hydrolytic enzyme – lipase;
- Estimation of dehydrogenase enzyme and respiratory quotient in seeds;
- Estimation of food reserve composition during seed germination.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignments
- Laboratory experiments
- Group exercises on biochemical estimations

IX. Learning outcome

By learning this course, students will understand the fundamental theories and mechanism underlying in seed dormancy and germination which will be useful for both basic research and development.

X. Suggested Reading

Baskin C and Baskin JM. 2014. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Academic Press, Cambridge, UK.

Bewley J and Black M. 1994. *Physiology of Development and Germination*. Springer, New York.

Bewley JD, Bradford KJ, Hilhorst HWM and Nanogaki H. 2013. *Seeds: Physiology of Development, Germination and Dormancy*. Springer, New York.

Bewley JD and Black M. 1982. *Physiology and Biochemistry of Seeds in Relation to Germination*. Volume 2: Viability, Dormancy and Environmental Control.Springerlink, New York, USA

Benech-Arnold R and Rodolfo S. 2004. *Handbook of Seed Physiology: Applications to agriculture*. CRC Press., Florida, USA.
Black M and Bewley JD. 2000. *Seed Technology and its Biological Basis*. CRC Press. Florida, USA.
Bradbeer JW. 1988. *Seed Dormancy and Germination*. Chapman and Hall, New York, USA.
David R. Murray. 1985. *Seed Physiology*. Volume 2: Germination and Reserve Mobilisation. Academic Press, London, UK.
Heydecker W. 1985. *Seed Ecology*. Pennsylvania State University Press, USA.
Khan AA. 1977. *The Physiology and Biochemistry of Seed Dormancy and Germination*. North – Holland Publishing Company, USA.
Kozlowski TT. 2012. *Seed Biology: Importance, Development and Germination*. (Vol. I). Academic Press Inc., New York.
Maiti RK, Sarkar NC and Singh VP. 2012. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur.
Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, Rajasthan.
Mayer AM and Mayber AP. 1963. *Germination of Seeds*. Pergamon Press, Oxford, New York.
Prakash M. 2011. *Seed Physiology of Crops*. Satish Serial Publishing house. Azadpur. New Delhi.
Roberts EH. 1972. *Viability of seeds*. Springerlink, New York, USA.

XI. Suggested e-books

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https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1756-1051.2000.tb01610.x
https://www.elsevier.com/books/seeds/baskin/978-0-12-416677-6
https://books.google.co.in/books/about/Physiology_and_Biochemistry_of_ Seeds_in.html?id=91nsCAAAQBAJ&printsec=frontcover&source=kp_read_ button&redir_esc=y#v=onepage&q&f=false
https://books.google.co.in/books/about/The_Germination_of_Seeds.html? id=aV62AgAAQBAJ&printsec=frontcover&source=kp_ read_button&redir_ esc=y#v=onepage&q&f=false
https://books.google.co.in/books/about/Seed_Dormancy_and_Germination. html?id=18HeBwAAQBAJ&printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false

XII. Suggested websites

https://agriinfo.in/botany/18/
https:/sproutnet.com/seed-dormancy/
https://www.britannica.com/science/germination
http://www.biologyreference.com/Re-Se/Seed-Germination-and-Dormancy.html
https://www.intechopen.com/books/advances-in-seed-biology/seed-dormancy

I. Course Title : Seed Production Principles and Techniques in Field Crops*

II. Course Code : SST 503

III. Credit Hours : 3 (2+1)

IV. Why this course?

Awareness about the use of quality seed among farmers enhances the seed demand and seed trade. To meet the seed demand, production should be carried out in large areas. Hence, it is essential to learn about the production principles and techniques of quality seed production.

V. Aim of the course

To impart knowledge on principles and practices involved in quality seed production of field crops.

VI. Theory

Unit I

Importance of seed – seed quality concept – factors influencing seed production; generation system of seed multiplication – classes of seed, stages of seed multiplication in varieties and hybrids – seed multiplication ratio (SMR) – seed replacement rate (SRR) – seed renewal period (SRP) – varietal replacement rate (VRR).

Unit II

Genetic and agronomic principles of variety and hybrid seed production; methods and techniques of seed production in varieties and hybrids of important cereals and millets – wheat, oat, rice, maize, sorghum and pearl millet; varietal seed production in small millets – finger millet, fox tail millet, little millet, kodo millet, proso millet and barnyard millet.

Unit III

Methods and techniques of varietal seed production in major pulses – black gram, green gram, cowpea, chickpea, horse gram, soybean and lentil – varietal and hybrid seed production in red gram.

Unit IV

Methods and techniques of seed production in major oil seed crops – groundnut, sesame – varietal and hybrid seed production in sunflower, castor and mustard; varietal seed production in minor oilseed crops (safflower, linseed, niger) – varietal and hybrid seed production in cotton – varietal seed production in jute.

Unit V

Seed production planning for varieties and hybrids of major crops; participatory seed production – seed hubs, seed village concept and community seed bank.

VII. Practical

- Seed selection – quality of seed on field establishment;
- Sowing and nursery management techniques;
- Planting – age of seedling on crop establishment – rice and pearl millet;
- Isolation distance and border rows in hybrid seed production field – space and barrier isolation; modifying isolation based on border rows in maize;
- Planting design for hybrid seed production – rice, maize, pearl millet, cotton, red gram, sunflower;
- Practicing breeding tools for hybrid seed production – detasseling – emasculation and dusting;
- Study on methods of achieving synchronization – rice, bajra, sunflower;
- Practicing supplementary pollination – rice and sunflower;
- Study on foliar nutrition and influence on seed yield;
- Practicing roguing operation – identification of off-types, pollen shedders, shedding tassels, partials, selfed bolls;
- Pre and post harvest sanitation operations – cereals, millets and pulses;
- Estimation of shattering and shattering loss; study on insitu germination and loss;
- Visit to seed production fields;
- Visit to seed industry;
- Seed production planning and economics of seed production – varieties;
- Seed production planning and economics of seed production – hybrids.

VIII. Teaching methods

- Classroom lectures
- Power point presentation
- Student assignment presentation and group tasks
- Field and laboratory experiments
- Field visits

IX. Learning outcome

Successful completion of this course enable student to take up seed production venture in scientific manner to ensure seed quality and profitability.

X. Suggested Reading

Agrawal RL. 2019. *Seed Technology*. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.
Hebblethwaite PD. 1980. *Seed Production*. Butterworth Heinemann Ltd., London, UK.
Joshi AK and Singh BD. 2004. *Seed Science and Technology*. Kalyani Publishers, New Delhi.
Kulkarni GN. 2011. *Principles of Seed Technology*. Kalyani Publishers, New Delhi.
Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, Rajasthan.
McDonald MB and Copeland L. 1998. *Seed Production Principles and Practices*. CBS Publishers, New Delhi.
Mondal SS, Saha M and Sengupta K. 2009. *Seed Production of Field Crops*. New India Publishing Agency, New Delhi.
Singhal NC. 2003. *Hybrid Seed Production in Field Crops*. Kalyani Publications, New Delhi.Sen S and Ghosh N. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi.
Singhal NC. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi.

XI. Suggested e-books

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https://www.springer.com/in/book/9780412075513
https://www.nipabooks.com/info/9788190723763/seed-production-of-field-crops
https://www.amazon.in/Production-Field-Crops-Brajesh-Tiwari/dp/9380179405
https://www.cambridge.org/core/journals/journal-of-agricultural-science/article/seed-production-of-agricultural-crops-by-kelly-a-f-227-pages-harlow-longman-1988-price-2500-hard-covers-isbn-0-582-40410-x/8BE3C99DFDC0F02D48E CB53418504D10

XII. Suggested websites

https://agriinfo.in/botany/18/
http://www.fao.org/3/a-e8935e.pdf
http://www.agriquest.info/seed_production.php
http://agritech.tnau.ac.in/seed_certification/seedtech_index.html
http://coin.fao.org/coinstatic/cms/media/16/13666518481740/seed_enterprises_enhacement_and_development_project_in_sierra_leone_mission_1_report_.pdf

I. Course Title : Seed Production: Principles and Techniques in Vegetable Crops*

II. Course Code : SST 504

III. Credit Hours : 3 (2+1)

IV. Why this course?

Seed trade is mainly based on high value low volume seeds. Area under vegetable cultivation is increasing day by day, which demands high area under seed production. The thorough knowledge on vegetable seed production will enable the students to take up seed production venture in low volume high value crops.

V. Aim of the course

To impart knowledge on principles and practices involved in quality seed production of vegetable crops.

VI. Theory

Unit I

Importance and present status of vegetable seed industry – factors influencing vegetable seed production; varietal and hybrid seed production techniques in major solanaceous vegetable crops – tomato, brinjal, chilli; malvaceous vegetable crop – seed production techniques of bhendi.

Unit II

Varietal and hybrid seed production techniques in important cucurbitaceous vegetables – gourds and melons, cole crops – cauliflower, cabbage, knol-khol, root vegetables – carrot, beetroot, turnip, radish and other temperate/ hilly vegetable crops.

Unit III

Varietal seed production techniques in major leguminous vegetables – peas and beans; seed production techniques in leafy vegetables – amaranthus, palak, spinach, and lettuce.

Unit IV

Seed production techniques in tuber crops – potato, sweet potato, colocasia, tapioca and yam, seed-plot technique in potato – true potato seed (TPS) production techniques – seed production techniques in bulb crops – onion, garlic.

Unit V

Vegetative and clonal multiplication – methods, merits and demerits; clonal multiplication – potato, sweet potato, colocasia, tapioca and yam.

VII. Practical

- Identification of vegetable seeds;
- Study on sowing and nursery management;
- Study on transplanting and age of seedling on crop establishment;
- Studying floral biology of solanceous, malvaceous and cucurbitaceous vegetable crops;
- Studying floral biology of other vegetable crops;
- Practicing planting design for hybrid seed production;
- Modification of sex ratio in cucurbits;
- Practicing emasculation and pollination methods;
- Practicing roguing operations – identification of off-types – selfed fruits;
- Harvesting methods – single and multiple harvesting method;
- Practicing seed extraction methods – wet methods – tomato, brinjal, other cucurbitaceous fruits;
- Seed extraction – dry methods – chillies, bhendi, cucurbitaceous;
- Visit to seed production fields;
- Visit to private seed industry;
- Planning and economics of varietal seed production;
- Planning and economics of hybrid seed production.

VIII. Teaching methods

- Classroom lectures with power point
- Student assignment and presentations
- Field and laboratory experiments
- Demonstration
- Hands on training
- group tasks
- Field and industry visits

IX. Learning outcome

Successful completion of this course enable student to gain confidence and to become seed entrepreneur in high value low volume vegetable crops.

X. Suggested Reading

Agarwal RL. 2012. *Seed Technology*. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.
Chadha KL. 1995. *Advances in Horticulture*. Volume 1 to 13. Malhothra Publishing House, New Delhi.
George RAT. 1985. *Vegetable Seed Production*. Lonhman Inc., New York.
Hebblethwaite PD. 1980. *Seed Production*. Butterworth Heinemann Ltd, London, UK.
Kulkarni GN. 2011. *Principles of Seed Technology*. Kalyani Publishers, New Delhi.
Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, Rajasthan.
McDonald MB and Copeland L. 1998. *Seed Production: Principles and Practices*. CBS Publishers, New Delhi.
Sen S and Ghosh N. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.
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Vanangamudi K, Natarajan N, Srimathi P, Natarajan K, Saravanan T, Bhaskaran M, Bharathi A, Natesan P and Malarkodi K. 2006. *Advances in Seed Science and Technology*. Vol. 2. *Quality Seed Production in Vegetables*. Agro bios, Jodhpur.

XI. Suggested e-books

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http://203.64.245.61/fulltext-pdf/EB/1900-2000/eb0021.pdf
http://www.worldseed.org/wp-content/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf
https://trove.nla.gov.au/work/6862691?q&sort=holdings+desc&-=1541066209 257&versionId=45008917+251246346

XII. Suggested websites

https://agriinfo.in/botany/18/
http://agritech.tnau.ac.in/seed_certification/seedtech_index.html
http://www.yspuniversity.ac.in/vgc/caft/Compendium2017-18.pdf
https://www.hort.vt.edu/Welbaum/seedproduction/Principles5.html
http://www.agrimoon.com/wp-content/uploads/Seed-Production-of-Vegetable.pdf
http://www.ciks.org/downloads/seeds/4.%20Seed%20Production%20Techniques %20for%20Vegetables.pdf

I. Course Title : Seed Production Techniques in Fruits, Flowers, Spices, Plantation and Medicinal Crops

II. Course Code : SST 505

III. Credit Hours : 3 (2+1)

IV. Why this course?

At present seed industry is expanding towards the low volume and high value seeds. Domestication of fruit, plantation and medicinal plants enable the farmers to cultivate commercially. The seed demands in these crops are increasing day by day. Hence, it is essential to learn the techniques of seed production in fruits, flowers and plantation crops.

V. Aim of the course

To impart comprehensive knowledge on seed production techniques in fruits, flowers, spices, plantation and medicinal crops.

VI. Theory

Unit I

Scope for seed production in fruits, flowers, spices, plantation and medicinal crops; factors influencing seed production and quality; propagation methods – seed and clonal propagation; seed and seedling standards; propagation and seed production techniques in major tropical, sub-tropical and temperate fruit crops; seed orchards – seed collection, extraction processing and storage techniques.

Unit II

Seed production techniques in commercially important flower crops – nursery management, clonal propagation, planting, seed crop management, post-harvest seed handling and storage techniques.

Unit III

Seed production techniques in commercially important seed spices and other spices – nursery management, sowing, seed crop management and post-harvest seed handling and storage techniques.

Unit IV

Seed production in commercially important plantation crops – mother tree selection – criteria – nursery management, elite seedling production, planting, plantation management, post-harvest handling and storage techniques.

Unit V

Methods of quality seed production in commercially important medicinal plants – nursery management, sowing, seed crop management, post-harvest handling and storage methods.

VII. Practical

- Study on the floral biology and pollination mechanism;
- Identification of seeds of fruits, flowers, spices, plantation and medicinal crops;
- Selection of mother plants and trees – phenotypic characters and genotypic characters;
- Study on different types of clonal and vegetative propagules;
- Seed and clonal standards of vegetatively propagating crops;
- Germination improvement treatments for seeds and vegetative propagules;
- Study on selection of planting materials and sowing methods;
- Nursery management practices for elite seedling production;
- Seed extraction methods – wet method and dry method;
- Post harvest seed handling – seed grading, upgrading techniques
- Study of seed storage techniques;
- Practicing seed germination enhancement techniques in fruits, spices and plantation crops;

- Practicing seed germination enhancement techniques in flowers and medicinal crops;
- Planning for seed production – economics of seed production in flower crops;
- Visit to mother tree orchard;
- Visit to plantation and orchard.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentation
- Group exercise
- Field visit

IX. Learning outcome

Successful completion of this course enables the students to take up elite seed and seedling production on commercial scale.

X. Suggested Reading

Chadha KL. 1995. *Advances in Horticulture*. (Volume 1 to 13). Malhotra Publishing House, New Delhi.

Hartman HT and Kester DE. 2000. *Plant Propagation: Principles and Practices*. Prentice Hall, New Jersey, USA.

Singh SP. 2001. *Seed Production of Commercial Vegetables*. Agrotech, New Delhi.

Vanangamudi K and Natarajan K. 2008. *Advances in Seed Science and Technology. Quality Seed Production in Spices, Plantation, Medicinal and Aromatic crops* (Vol. 5). Agrobios. Jodhpur.

Vanangamudi KM Prabu and Lakshmi S. 2012. *Advances in Seed Science and Technology Vol. 7. Flower Seed Production*. Agrobios, Jodhpur.

XI. Suggested e-books

http://www.worldseed.org/wpcontent/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4233836/

https://www.academia.edu/35629702/Hybrid_Seed_Production_and_Flowers

http://www.agrimoon.com/horticulture-icar-ecourse-pdf-books/

https://cbp.icar.gov.in/EBook.aspx

XII. Suggested websites

www.cimap.res.in/english/index.php

www.dmapr.org.in/ampurs.kau.in/basic-page/publications

http://ecoursesonline.iasri.res.in/course/view.php?id=153

http://ecoursesonline.iasri.res.in/course/view.php?id=612

http://www.celkau.in/Crops/Plantation%20Crops/Rubber/production.aspx

http://sbc.ucdavis.edu/Courses/Seed_Production/

I. Course Title : Seed Production Techniques in Forage, Pasture and Green Manure Crops

II. Course Code : SST 506

III. Credits Hours : 2 (1+1)

IV. Why this course?

Agriculture and animal husbandry in India is interwoven and livestock is the source of income when crop failed. To feed the livestock population, cultivation and seed production of fodder and forage crops are much important. Likewise green manure crops maintain soil health, which created heavy demand for quality seed.

Hence, study of seed production techniques in these crops will help to produce quality seeds to meet the growing needs.

V. Aim of the course

To impart knowledge on basic principles and methods of quality seed production in forage and green manure crops.

VI. Theory

Unit I

Scope and importance of seed production in forage, pasture and green manure crops – factors influencing seed production – seasonal influence; problems and constraints in seed production – seed set, shattering and seed dormancy; vegetative and clonal propagules and apomictic seed.

Unit II

Quality seed production techniques in major fodder crops – lucerne, hedge lucerne, leucaena, fodder sorghum, fodder maize and oats.

Unit III

Seed and planting material production techniques of major forage grasses – bajra -napier grass, guinea grass, deenanath grass and *Cenchrus* sp.; forage legumes *Stylosanthus*, cowpea and berseem.

Unit IV

Seed production techniques in major green manure crops – *Glyricidia*, *Sesbania* sp., sunnhemp, daincha, jute and *Tephrosia* sp.

Unit V

Post-harvest seed handling – processing, threshing, grading and upgrading; dormancy breaking and germination improvement – quality standards for seed and vegetative propagules.

VII. Practical

- Seed collection and identification of seeds;
- Estimation of seed setting and shattering loss;
- Maturity indices – determination of physiological and harvestable maturity;
- Seed extraction and threshing methods;
- Separation of ill filled seeds – practicing different methods;
- Study of seed and clonal materials – standards;
- Quality of planting material and vegetative propagules on crop establishment;
- Seed quality analysis in forage and fodder crops – tiller wise quality analysis;
- Seed quality analysis in determinate and indeterminate crops;
- Study on effect of ratooning on seed quality;
- Practicing seed quality enhancement techniques;
- Practicing different seed extraction and dormancy breaking treatments;
- Preparation of vegetative propagules and planting;
- Planning for seed production in fodder and green manure crops;
- Economics of seed production in fodder, forage crops and green manure crops;
- Visit to forage and fodder seed production farms.

VIII. Teaching Methods

- Classroom teaching
- Power point presentations
- Students assignment and presentation
- Field and laboratory experiments
- Hands on training
- Demonstration
- Field visit

IX. Learning outcome

After completion of course the students gain confidence to start a seed venture on forage and green manure crops.

X. Suggested Reading

FAO. 2007. *Quality Declared Seed System*. FAO Plant Production and Protection Publication, FAO, Rome.

Farity DT and Hampton JC. 1997. *Forage Seed Production*. Vol. I. *Temperate Species*. CAB International Publications. UK.

Froma J. 1997. *Temperate Forage Legumes*. CAB International Publications. UK.

Gutterridge RG. 1997. *Forage Tree Legumes in Tropical Agriculture*. CAB International Publications, UK.

Masilamani S and Sivasubramanian K. 2016. *Seed Production in Green Manures*. Kalyani Publications, New Delhi.

XI. Suggested e-books

https://www.cabi.org/bookshop/book/9780851992143
https://cgspace.cgiar.org/handle/10568/49375
http://www.fao.org/docrep/009/a0503e/a0503e00.htm
http://www.igfri.res.in/pdf/old_bulletins/tropical_pasture.pdf
https://cgspace.cgiar.org/bitstream/handle/10568/4479/Seed.pdf?sequence= 1&isAllowed=y

XII. Suggested websites

www.igfri.res.in/
https://cgspace.cgiar.org/handle/10568/4479
https://www.euroseeds.eu/grasses-and-clovers
https://www.sare.org/learning-center/green-manures
www.ndri.res.in/ndri/Design/forageres_mag_cen.html
http://orgprints.org/30588/1/Sort%20Out%20Your%20Soil.pdf

I. Course Title : Seed Legislation and Certification*
II. Course Code : SST 507
III. Credit Hours : 3 (2+1)

IV. Why this course?

Awareness on usage of quality seeds among farmers increases the seed demand. To regulate the seed quality and to avoid the spurious seeds in the market, seed legislation and certification procedures should be known by all the stake holders. This course will provide comprehensive knowledge on seed policies, seed law enforcement and seed certification procedures to the learners.

V. Aim of the course

To impart knowledge on seed legislation in relation to seed certification and quality control systems.

VI. Theory

Unit I

Genesis of seed Industry in India; seed quality control – concept and objectives; regulatory mechanisms – Seed Act (1966) – Seed Rules (1968) – statutory bodies – Central Seed Committee – Central Seed Certification Board.

Unit II

Seed Control Order (1983) – New Policy on Seed Development (1988) – Exim Policy – National Seed Policy (2002) – Plant Quarantine Act.

Unit III

Introduction to WTO and IPR – UPOV and its role – OECD seed certification schemes – PPV & FR Act (2001) and Rules (2003) – Seed Bill (2004 and 2011): Seed certification system in SAARC countries, Europe, Canada, Australia and USA.

Unit IV

Seed certification – history and objectives; general and specific crop standards, field and seed standards; seed certification agency – role of certification agency/ department and seed certification officers, phases of seed certification; field inspection – counting procedures – liable for rejection (LFR) – downgrading and partial rejection – reporting.

Unit V

Post-harvest inspection – construction of seed lot number; seed sampling – testing – labeling, sealing and grant of certificate – types and specifications for tags and labels; seed lot validity and revalidation; appellate authority, stop sale order, penalties records and registers to be maintained by seed processing units and seed dealers – verification procedures, role of seed analyst and seed inspector in quality regulation.

VII. Practical

- Preparation of sowing report – varieties – transplanted and direct sown crops and hybrids;
- Verification of sowing report – seed certification procedures;
- Field inspection – estimation of area and isolation distance, stages of inspection for varieties and hybrids – procedures;
- Practicing field counting procedures – methods for row planting, broadcasted – varieties;
- Practicing field counting procedures – direct sown and transplanted crops – varieties;
- Study on field counting procedures – hybrids – planting design, planting ratio and block method and double count;
- Identification of contaminants – genetic and physical contaminants, procedure to remove partials, pollen shedders and shedding tassels;
- Assessing and calculation of field standards for important crops;
- LFR, partial rejection and downgrading – reasons, procedures and preparation of reports;
- Yield estimation – single and multiple harvest crops;
- Post harvest inspection – groundnut, cotton, pulses;
- Inspection and maintenance (licence and renewal) of records in processing unit – float test, preparation of processing report and seed lot number construction;

- Visit to seed certification agency/ department;
- Visit to grow-out test field;
- Visit to seed retail shop – procedures followed by Seed Inspector, verification of records and reporting;
- Procedure to issue tag, specification, bagging, tagging, labelling and sealing.

VIII. Teaching methods

- Classroom lectures
- Guest lectures
- Student assignments and presentations
- Demonstrations
- Field visits

IX. Learning outcome

This course will be useful to develop human resource on seed certification and legislation. Successful completion of this course enables students to become a Seed Certification Officer and Seed Inspector.

X. Suggested Reading

Agarwal RL. 2012. *Seed Technology*. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.

Anon. 2016. *Manual of Seed Certification Procedures*. Directorate of Seed Certification, Coimbatore, Tamil Nadu.

Chakrabarthi SK. 2010. *Seed Production and Quality Control*. Kalyani Publishers, New Delhi.

Mishra DK, Khare D, Bhale MS and Koutu GK. 2011. *Handbook of Seed Certification*. Agrobios, Jodhpur, Rajasthan.

Neema NP. 1986. *Principles of Seed Certification and Testing*. Allied Publishers, New Delhi

Ramamoorthy K, Sivasubramaniam K and Kannan M. 2006. *Seed Legislation in India*. Agrobios, Jodhpur, Rajasthan.

Renugadevi J, Srimathi P, Renganayaki PR and Manonmani V. 2012. *A Handbook of Seed Testing*. Agrobios, Jodhpur, Rajasthan.

Sharma P. 2008. *Seed Legislation*. Gene-tech Book Publishers, New Delhi.

Trivedi PC. 2011. *Seed Technology and Quality Control*. Pointer Publications, Jaipur, Rajasthan.

Tunwar NS and Singh SV. 2003. *Indian Minimum Seed Certification Standards*. Central Seed Certification Board, Ministry of Agriculture, GOI, New Delhi.

XI. Suggested e-books

http://cms.tn.gov.in/sites/default/files/documents/seed-certification-0.pdf

http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material/INDIAN-MINIMUM-SEED-CERTIFICATION-STANDARDS.pdf

https://www.india.gov.in/my-government/documents/e-books

https://books.google.co.in/books/about/Principles_of_Seed_Certification_and_ Tes.html?id=SQWHAAAACAAJ&redir_esc=y

https://dl.sciencesocieties.org/publications/books/tocs/cssaspecialpubl/theroleofseedce

XII. Suggested websites

www.fao.org

www.agri.nic.in

www.agricoop.nic.in

www.gov.mb.ca

http:/agritech.tnau.ac.in

www.betterseed.org

www.oecd.org/india/

http://www.tnagrisnet.tn.gov.in/

https://pir.sa.gov.au/_data/assets/pdf_file/0003/148134/SeedCertification Manual.pdf

I. Course Title : Post Harvest Handling and Storage of Seeds*
II. Course Code : SST 508
III. Credit Hours : 3 (2+1)

IV. Why this course?

Healthy seeds are the demanding enterprise of the recent era for the production of high yield in the next season. The seeds must be well processed and stored for the maintenance of high-yielding crop. During storage, major losses of seeds are caused by various biotic and abiotic factors. There is a need apply proper post harvest handling and storage techniques, which ultimately improve the market value and quality of the seed.

V. Aim of the course

To impart knowledge on principles, techniques and methods of seed processing, treatment and storage.

VI. Theory

Unit I

Seed processing – objectives and principles; processing sequence – threshing, shelling, ginning, extraction methods; drying – principles and methods; seed cleaning, grading, upgrading – methods – machineries and equipment – scalper, pre-cleaner, cleaner cum grader, specific gravity separator, indented cylinder, disc separator, spiral separator, velvet separator, magnetic separator, electronic colour sorter – working principles and functions.

Unit II

Online seed processing – elevators and conveyers – processing plant – specifications, design and layout; mechanical injury – causes and detection – management.

Unit III

Seed treatment – methods – pre and mid storage seed treatments, seed treating formulations and equipments; packaging materials – types – bagging and labeling; seed blending – principle and methods.

Unit IV

Seed storage – purpose and importance – factors affecting storage, optimum condition for storage of different seeds; storage principles – Harrington's thumb rule – concepts and significance of moisture equilibrium – maintenance of safe seed moisture – physical, physiological, biochemical and molecular changes during seed storage – storage behaviour of orthodox and recalcitrant seeds – prediction of viability – viability nomograph.

Unit V

Methods of seed storage – modified atmospheric storage – ultra dry storage – vacuum storage – cryopreservation – germplasm storage – gene banks – NBPGR, IPGRI and National seed storage laboratory; seed storage godown – structure – maintenance – sanitation.

VII. Practical

- Seed extraction – wet and dry methods;
- Seed processing sequence for different crops;
- Design of processing plant – equipments – estimation of processing efficiency;

- Seed drying methods – principle and methods;
- Practicing seed grading – upgrading techniques;
- Delinting methods – assessment of mechanical damage;
- Visit to seed processing unit;
- Seed packaging – effect of packaging materials on seed longevity;
- Prediction of viability during storage – viability nomograph and accelerated ageing test;
- Assessing physical changes during seed storage;
- Assessing physiological changes during seed storage;
- Assessing biochemical changes during seed storage;
- Storage behaviour of recalcitrant seeds;
- Pre-storage seed treatments – protectants – antioxidants – halogens;
- Practicing seed blending methods;
- Seed storage godown – sanitation, fumigation – visit to seed storage godown and cold storage unit.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignment and presentation
- Processing experiments
- Demonstration
- Hands on training
- Exposure and field visits

IX. Learning outcome

The students will understand the principles and mechanism involved in seed processing, storage techniques and management practices to arrest the seed deterioration. Students will also acquire skill on seed handling and storage methods on commercial basis.

XI. Suggested Reading

Barton LV. 1961. *Seed Preservation and Longevity*, (Vol. 1). Leonard Hill, London.

Gregg BR, Law AG, Virdi SS and Balis JS. 1970. *Seed Processing*. Avion printers, New Delhi.

Gupta D. 2009. *Seeds: their conservation principles and practices*. Sathish serial publishing house. New Delhi.

Justice OL and Bass LN. 1978. *Principles and Practices of Seed Storage*. Agriculture Hand Book No. 506, Castle House Publication Ltd., Washington.

Kulkarni GN. 2011. *Principles of Seed Technology*. Kalyani Publishers, New Delhi.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, Rajasthan.

Padmavathi S, Prakash M, Ezhil Kumar S, Sathiyanarayanan G and Kamaraj A. 2012. *A Text book of Seed Science and Technology*, New India Publishing Agency, New Delhi.

Sen S and Ghosh N. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi.

Singhal NC. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi.

XI. Suggested e-books

http://dfsc.dk/pdf/Handbook/chapter8_internet.pdf

https://naldc.nal.usda.gov/download/CAT87208646/PDF

https://www.springer.com/in/book/9780792373223

http://203.64.245.61/fulltext-pdf/EB/1900-2000/eb0021.pdf

https://www.kopykitab.com/ebooks/2016/05/6997/sample/sample_6997.pdf

https://trove.nla.gov.au/work/6862691?q&sort=holdings+desc&-=1541066209257 &versionId=45008917+251246346

http://www.worldseed.org/wp-content/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf

XII. Suggested websites

http://www.fao.org/3/a-ah803e.pdf
agritech.tnau.ac.in/seed_certification/seedtech_index.html
http://ecoursesonline.iasri.res.in/mod/page/view.php?id=17806
http://www.bcseeds.org/wp-content/uploads/2015/01/Seed-Processing-2015-update.pdf
https://www.carolinafarmstewards.org/wpcontent/uploads/2012/05/Seed Processingand StorageVer_1pt3.pdf

I. Course Title : Seed Quality Testing and Enhancement*
II. Course Code : SST 509
III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed is the basic input in agriculture and the productivity is mainly depends on field population of plants. By sowing quality seeds, population can be maintained. Hence, it is necessary to know the quality parameters to be analyzed. Through seed treatments, the performance of seed can be improved. Especially to address the drought and climate change the knowledge on seed enhancement techniques is much essential.

V. Aim of the course

To impart knowledge on principles, techniques and methods of seed testing and seed quality enhancement.

VI. Theory

Unit I

Seed testing – history and development; seed testing in India; ISTA and its role in seed testing; seed lot and size, types of seed and size, samples – sampling – intensity and methods, sampling devices, receipt and registration of submitted samples in the laboratory and sub sampling; purity analysis – components and procedure – determination of other distinguishable varieties (ODV) and test weight determination – application of heterogeneity test – method of testing coated and pelleted seeds; seed moisture estimation – principles and methods, application of tolerances.

Unit II

Seed germination test – requirements, media and methods – seedling evaluation, tolerance and reporting results; viability test (TZ test) – principle, procedure and evaluation; vigour tests – concept of seed vigour and vigour test – types of vigour tests – direct and indirect tests – physical, physiological and biochemical tests – principles and methods; seed health test – principles and methods.

Unit III

Genetic purity assessment – laboratory methods – physical, chemical, biochemical and molecular tests – growth chamber and field testing (Grow Out Test) methods; testing of GM seeds; storage of guard sample – referral test; application of tolerance in seed testing; advanced non destructive techniques of seed quality analysis – soft x-ray imaging – hyper spectral imaging, thermal imaging – spectroscopy – e-nose and machine vision techniques.

Unit IV

Seed quality enhancement techniques – history and development; classification – physical, physiological and protective seed treatments – special seed treatments; physical seed treatment – liquid floatation, specific gravity separation, irradiation, electric and electro-magnetic seed treatments – principles and methods – seed pelleting and coating principles, purpose and methods.

Unit V

Physiological seed enhancement treatments – seed infusion, seed priming – principles and methods – physiological, biochemical and molecular mechanisms; pre-germination and fluid drilling techniques; biological seed treatments – microbial inoculation; organic seed treatment – integrated seed treatment – concept and methods of designer seed.

VII. Practical

- Seed testing – sampling and dividing methods;
- Determination of seed test weight and heterogeneity test;
- Physical purity analysis – components, procedure, reporting results;
- Seed moisture estimation – methods and equipments;
- Conduct of seed germination test and seedling evaluation;
- Conduct of quick viability (tetrazolium) test and evaluation;
- Conduct of vigour tests – direct, indirect test and special tests;
- Genetic purity assessment – laboratory and conventional methods – image analysis for seed quality;
- Conducting different seed health tests to identify bacteria, fungi and insects;
- Visit to seed testing laboratory;
- Seed enhancement techniques – practicing physical treatments and water floatation techniques;
- Seed coating and pelleting – uses of adhesives and filler materials;
- Performing seed priming – hydro, halo and bio-priming – solid matrix priming;
- Practicing seed infusion and microbial inoculation treatments;
- Practicing pre-germination technique;
- Studying integrated seed treatment/ designer seed treatment.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentations
- Laboratory experiments
- Demonstration
- Hands on training
- Exposure visits

IX. Learning outcome

Successful completion of this course by the students will be useful to acquire technical skill on seed quality analysis which leads to the development of human resource on seed quality analysis.

X. Suggested Reading

Agrawal PK. 1993. *Hand book of Seed Testing*. Ministry of Agriculture, GOI, New Delhi

Agrawal RL. 1997. *Seed Technology*. Oxford & IBH.

Agrawal PK and Dadlani M. 1992. *Techniques in Seed Science and Technology*. 2nd Ed. South Asian Publications.

Chakrabarthi SK. 2010. *Seed Production and Quality Control*. Kalyani Publishers. New Delhi.
Chalam GV Singh A and Douglas JE. 1967. *Seed Testing Manual*. ICAR and United States Agency for International Development, New Delhi.
Copeland LO and McDonald MB. 2001. *Principles of Seed Science and Technology*. 4th Ed. Kluwer Academic publishers, USA.
International Seed Testing Association. 2018. *Handbook on Seedling Evaluation*, 4th Edition, Published by ISTA, Zurichstr, Switzerland.
International Seed Testing Association. 2019. *International Rules for Seed Testing* 2019. Published by ISTA, Zurichstr, Switzerland.
ISTA. 1999. *Seed Science and Technology*, 27th supplement.
Renugadevi J, Srimathi P, Renganayaki PR and Manonmani V. 2012. *A Hand book of Seed Testing*. Agrobios. Jodhpur, Rajasthan.
Tridevi PC. 2011. *Seed Technology and Quality Control*. Pointer Publication. Jaipur, Rajasthan.
Vasudevan SN, Doddagowder SR, Rakesh CM and Patil SB. 2013. *Seed Testing and Quality Control*. Agrotech Publications, Udaipur, Rajasthan.

XI. Suggested e-books

http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material/INDIAN MINIMUM SEED CERTIFICATION STANDARDS.pdf.
www.kopykitab.com/Seed-Testing-and-Quality-Control-by-Vasudevan-SN
https://www.jstor.org/stable/10.14321/j.ctt7zt51m
https://link.springer.com/chapter/10.1007/978-1-4615-1619-4_13
https://www.researchgate.net/publication/269694458_QUALITY_SEED_ PRODUCTION_ITS_TESTING_AND_CERTIFICATION_STANDARD
https://www.seedtest.org/upload/cms/user/ISTAMethodValidationforSeed Testing-V1.01.pdf
https://www.intechopen.com/books/new-challenges-in-seed-biology-basic-and-translational-research-driving-seed-technology/recent-advances-in-seed-enhancements

XII. Suggested websites

http://agritech.tnau.ac.in/seed/Seed_seedtesting.html
https://core.ac.uk/download/pdf/85210907.pdf
https://www.betterseed.org/resources/seed-testing-accreditation-schemes/
http://sbc.ucdavis.edu/About_US/Seed_Biotechnologies/Seed_Enhancement/
https://www.seedtest.org/en/international-rules-for-seed-testing-content-1-1083. html

I. Course Title : Seed Technology of Tree Species
II. Course Code : SST 510
III. Credit Hours : 2 (1+1)

IV. Why this course?

Tree seed production is an important primary niche for carrying forward sustainable agriculture and forest resource management. Knowledge of the seed biology of a tree species is essential to successful seed production and handling of tree crops. The sexual life cycle must be known to plan for genetic improvement, production, collection, conditioning, storage and planting of the seeds for propagation of trees.

V. Aim of the course

To make the students gain knowledge on seed production and handling techniques of various tree species.

VI. Theory

Unit I

Importance of tree seeds – seed quality in plantation establishment – scope of seed production in tree species; seed structure and its significance in natural regeneration of forest species.

Unit II

Reproductive biology – angiosperms and gymnosperms – reproductive age – seasonal influence on flowering – reproductive efficiency; factors influencing seed set – pollination – pollinating agents – self incompatibility – seed dispersal – mode and mechanism of dispersal.

Unit III

Seed stand – selection and delineation – seed production area – seed zone – selection criteria for candidate, plus and elite tree; seed orchards – definition – types – seedling and clonal seed orchard – pollen dilution zone – seed orchard establishment and management; OECD certification programmes for forest reproductive materials and seeds – ISTA certification standards for tree species.

Unit IV

Physiological maturity – maturity indices – determining optimum harvestable maturity; seed collection – methods – factors influencing seed collection – precautions in collection of recalcitrant seeds; seed extraction – methods – wet, dry and cone extraction; drying – critical moisture content – seed processing; dormancy – types of dormancy in tropical, sub tropical and temperate tree seeds – dormancy breaking treatments; recalcitrant seeds – mechanism.

Unit V

Seed production and handling techniques in important tree borne oil seeds (*Madhuca, Pongamia*, *Azadirachta*, *Simaruba*, *Callophyllum*), timber (teak, sandal, pine, cedar, red sanders, shisham), fuel wood (*Acacias*), pulp wood (Bambusa, *Ailanthus*, *Casuarina*, *Melia*, *Eucalyptus*), fodder (*Leucaena, Albizzia*) and ornamental (*Cassia*, *Delonix*) tree species.

VII. Practical

- Study of tree seed structure – internal and external structures;
- Study on phenology of different tree species;
- Selection procedure of candidate and plus trees;
- Assessment of seed set, physiological and harvestable maturity;
- Assessing natural regeneration in different tree species;
- Study on seed dispersal methods and dispersal distance in different species;
- Seed collection techniques in important tree species – seed collection – orthodox and recalcitrant seeds – safety measures during collection;
- Seed extraction methods – wet and dry extractions – fruits, pods, cones, etc.;
- Study on different seed drying methods and precautions;
- Practicing seed grading and upgrading techniques;
- Practicing seed dormancy breaking methods;
- Germination improvement treatments for elite seedling production;
- Study on storage of recalcitrant seed;
- Estimation of critical moisture content for safe storage;
- Visit to seed production area and seed orchard;
- Visit to tree seed processing unit.

VIII. Teaching methods

- Classroom lectures

- Power point presentations
- Student assignments and presentation
- Group exercise
- Laboratory experiments
- Field visit to seed orchard

IX. Learning outcome

Knowledge of the seed biology of a tree species enable to produce good quality seeds, handling and prevent loss of seeds. The knowledge on sexual life cycle enables them to plan for genetic improvement, production, collection, conditioning, storage, and planting of the seeds.

X. Suggested Reading

Dennis AJ, Schepp EN, Green RJ and West cott DA. 2007. *Seed Dispersal*. Agrobios, Jodhpur.
Khanna LS. 1993. *Principles and Practices of Silviculture*. Khanna Bandhu, Dehradun, India.
Lars Schmidt 2000. *Guide to Handling of Tropical and Sub Tropical Forest Seed*. Danida Forest Seed Centre, Denmark.
Negi SS. 1998. *Forest Tree Seed*. International Book Distributors, Dehradun, India.
Ram Prasad and Khandya AK. 1992. *Handling of Forestry Seeds in India*. Associated Publishers, New Delhi.
Sivasubramaniam K, Raja K and Geetha R. 2012. *Recalcitrant Seeds – Causes and Effects*. Sathish Serial Publishing House. Azadpur, New Delhi.
Umarani R and Vanangamudi K. 2004. *An Introduction to Tree Seed Technology*. International Book Distributors, Dehradun.
Vanangamudi K, Natarajan K, Saravanan J, Natarajan N, Umarani R, Bharathi A and Srimathi P. 2007. *Advances in Seed Science and Technology: Forest Tree Seed Production* (Vol. 4). Agrobios, Jodhpur
Willan RL. 1985. *A guide to Forest Seed Handling*. FAO, Rome
Zoebel B and Talbert TT. 1984. *Applied forest tree improvement*. Joh willey and Sons, New Yark.

XI. Suggested e-books

http://www.fao.org/3/a-ah803e.pdf
http://www.fao.org/3/ad232e/AD232E01.htm
https://www.springer.com/gp/book/9783540490289
http://www.fao.org/docrep/006/ad232e/ad232e00.htm
http://envis.nic.in/ifgtb/pdfs/Tree%20Seed%20Management.pdf
https://www.forestry.gov.uk/PDF/FCBU054.pdf/$FILE/FCBU054.pdf
https://www.forestry.gov.uk/PDF/FCBU059.pdf/$FILE/FCBU059.pdf

XII. Suggested websites

www.ista.org.in
ifgtb.icfre.org/index.php
http://www.kfri.res.in/research.asp
http://www.fao.org/3/ad232e/AD232E21.htm
https://www.srs.fs.usda.gov/pubs/gtr/gtr_so107.pdf
http://www.sfri.nic.in/pdf_files/Seed%20Technology.pdf

I. Course Title : Seed Industry and Marketing Management
II. Course Code : SST 511
III. Credit Hours : 2 (1+1)

IV. Why this course?

India has a vibrant seed market. Over the years, the seed industry has evolved side by side with Indian agriculture. Indian seed industry is the fifth largest seed market in the world. This course will provide insights in seed industry development and better management of seed industry and seed marketing.

V. Aim of the course

To empower the students to become seed entrepreneurs by imparting knowledge on seed industry management and marketing strategies.

VI. Theory

Unit I

Introduction to seed industry – genesis, growth and structure of seed industry – mission and objectives – present status of Indian and global seed industry – role of seed industry in Indian agriculture; government initiatives – seed hubs, seed villages and community seed production system.

Unit II

Seed industry – organization set up and functions – public, private, MNC's, seed corporations; structure of small, medium and large seed industries, components of seed industry – public private partnership – custom seed production – risk management – human resource – infrastructure – processing unit – storage go down.

Unit III

Seed production and distribution systems in state and central government; seed supply chain systems – seed production and distribution – planning, organization and coordination, staffing, assembling of resources; cost of seed production – overhead charges.

Unit IV

Seed marketing – definition – importance – role of marketing; type of markets – domestic and global market – problems and perspectives; marketing policies – seed marketing schemes – marketing channels, responsibilities of dealers – marketing mix.

Unit V

Seed demand forecasting – purpose – methods and techniques; indenting and seed dispatch procedures and forms – seed store records – maintenance – missing link in seed supply chain; market intelligence – SWOT analysis; seed cost analysis; seed pricing – policy – components of seed pricing – factors – local market rate (LMR) – fixation of procurement and sale price of seed.

VII. Practical

- Data collection on status of Indian and global seed industry;
- Assessing the factors influencing farmers preference and assessment of seed demand and supply;
- Planning for establishment of small, medium and large seed industry;
- Planning for establishment of seed production and processing unit;
- Economics of seed production – varieties and hybrids;
- Seed pricings and cost analysis;
- Exercise on fixing seed procurement and sale price;
- Study of marketing channels – domestic and international;
- Maintenance of carryover seeds – Assessing risk factors in seed industry and their management;

- Survey and interaction with seed dealers and distributors;
- Visit to state seed corporations;
- Visit to MNCs and expert discussion;
- Case studies and SWOT analysis;
- Visit to modern seed processing unit and advanced seed storage complex;
- Custom seed production, contract farming and procurement – procedures;
- Planning and preparation of project proposal for setup of a seed industry;
- Final practical examination.

VIII. Teaching methods

- Classroom lectures
- Survey
- Student assignment and presentation
- Economic analysis
- Group discussion
- Swot analysis
- Seed industry visit and interaction sessions

IX. Learning outcome

On completion of this course students will gain knowledge and confidence to manage seed industry and able to address the problems in seed industry and seed marketing.

X. Suggested Reading

Acharya SS and Agarwal NL. 2004. *Agricultural Marketing in India*. 4th Ed. Oxford and IBH.
Broadway AC and Broadway A. 2003. *A Text Book of Agri-business Management*.
Kalyani Singh AK and Pandey S. 2005. *Rural Marketing*. New Age Publications.
Kugbei S. 2008. *Seed Economics*. Scientific Publishers, Jodhpur, Rajasthan.
Sharma P. 2008. *Marketing of Seeds*, Green-Tech Book Publishers, New Delhi.
Singh G and Asokan SR. 1991. *Seed Industry in India: A Management Perspective* Oxford & IBH Publishing Co Pvt. Ltd., New Delhi.
Singh S. 2004. *Rural Marketing – Focus on agricultural Inputs*. Vikas Publishing House.

XI. Suggested e-books

https://link.springer.com/chapter/10.1007/978-1-4615-1783-2-15
http://www.fao.org/3/V4450E/V4450E00.htm
https://books.google.co.in/books?id=vPVlBos4WkYC
http://download.nos.org/srsec319new/319EL19.pdf
https://isengewant.de/Marketing-of-Seeds-By-Premjit-Sharma.pdf
https://www.kopykitab.com/A-Handbook-of-Seed-Processing-and-Marketing-by- Gaur-SC

XII. Suggested websites

www.gov.mb.ca
www.agricoop.nic.in
www.agri.nic.in
https://sathguru.com/seed/
http://www.fao.org/3/V4450E/V4450E03.htm
https://www.seednet.gov.in/smis/SMIS-User%20Manual.pdf
https://www.icrisat.org/seed-systems-models-lessons-learned/
https://www.bookdepository.com/Seed-Industry-India-Gurdev-Singh/

I. Course Title	:	**Seed Health Testing and Management**
II. Course Code	:	**SST 512**
III. Credit Hours	:	**2 (1+1)**

IV. Why this course?

Seeds are the foundation for crop production and seed health is related to food production in many ways. Healthy seeds, free from seed transmitted pathogens, are a prerequisite for sustainable food production. Seeds are routinely tested to prevent and control plant pests and pathogens that may affect seed quality, seed movement when introduced into new territories. A seed health test is also frequently a phyto-sanitary requirement imposed by national plant protection authorities. This course aids in timely detection and management of seed borne pest and diseases and supply of pest and disease free seeds in market.

V. Aim of the course

To acquaint the students with principle and practices of seed health testing and management of seed borne pathogens and storage insects.

VI. Theory

Unit I

History and economic importance of seed health in seed industry and plant quarantine – important seed borne and seed transmitted pathogens – role of microorganisms in seed quality deterioration – storage and field fungi – effect of storage fungi on seeds – factors influencing storage fungi and management.

Unit II

Transmission of pathogens – mode and mechanism – seed certification standards; mycotoxins – types and its impact on plant, animal and human health; seed health testing methods – direct examination, incubation, serological and molecular methods.

Unit III

Production of disease free seeds in agricultural and horticultural crops; management of seed borne pathogens – plant quarantine – Indian system and networking, post-entry quarantine and international systems – Pest Risk Analysis (PRA); Sanitary and Phytosanitary System (SPS) – certificates; International Seed Health Initiative (ISHI) on seed health standards.

Unit IV

Storage pests – insects, mites, rodents and their development – economic importance; insect infestation – factors influencing, sources and kinds, biochemical changes in stored seeds due to insect infestation; detection methods and estimation of storage losses; types of seed storage structures – domestic and commercial.

Unit V

Fumigation – principles and techniques – type of fumigants; preservatives and seed protectants on seed quality – non-chemical methods for managing seed storage pests – controlled and modified atmospheric storage – trapping devices – IPM for seed storage.

VII. Practical

- Detection of seed borne pathogens – direct examination;
- Detection of seed borne pathogens – incubation methods;
- Detection of seed borne pathogens – serological methods;
- Detection of seed borne pathogens – molecular methods;
- Study on seed transmission of seed borne fungi, bacteria and viruses;
- Identification of storage fungi;
- Management of seed borne pathogens – seed treatment methods;
- Identification of storage insects – internal and external feeders influencing insects;

- Study on the effect of pre harvest spray on field carryover storage pests;
- Estimation of storage losses due to pests;
- Methods of detection of insect infestation;
- Management of storage pests – pesticides, dose determination, preparation of solution and application;
- Management of storage pests – non-chemical management methods;
- Demonstration of controlled atmospheric storage;
- Safe handling and use of fumigants and insecticides;
- Visit to seed storage godowns.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignment and presentation
- Laboratory experiments
- Hands on training.

IX. Learning outcome

Successful completion of this course will provide knowledge on production of healthy seeds by timely detection and management of seed borne pathogens and storage pests to meet phyto-sanitary requirements.

X. Suggested Reading

Agarwal VK and Sinclair JB. 1996. *Principles of Seed Pathology*. Edition, CRC Press Inc. Boca Raton, FL.

Athanassiou CG and Arthur FH. 2018. *Recent advances in stored product protection*. Springer-Verlag, Germany

Cotton, RT. 2007. *Insect Pests of Stored grain and Grain products*. Burgess Publ. Co., Minneopolis, Minn., USA

Karuna V. 2007. *Seed Health Testing*. Kalyani Publishers, New Delhi.

Karuna V. 2009. *Fundamentals of Seed Pathology*. Kalyani Publishers, New Delhi.

Neergaard P. 1979. *Seed Pathology*. Vol. 1. The Macmillan Press Ltd.

Ranjeet K. 2017. *Insect Pests of Stored grain – Biology, Behaviour and Management Strategies*. Apple Academic Press, New York, USA.

XI. Suggested e-books

https://link.springer.com/book/10.1007/978-1-349-02842-9

https://www.crcpress.com/Principles-of-Seed-Pathology/Agarwal-Sinclair/p/book/9780429152856

https://books.google.co.in/books/about/Seed_Pathology.html?id=lvVJAAAAYAAJ &redir_esc=y

https://www.taylorfrancis.com/books/9781315365695

https://www.ebooks.com/en-us/610606/insects-of-stored-products/david-rees/

https://www.elsevier.com/books/insects-and-seed-collection-storage-testing-and-certification/kozlowski/978-0-12-395605-7

XII. Suggested websites

www.tnagrisnet.tn.gov.in/

www.storedgrain.com.au/

https://openlibrary.org/subjects/seed_pathology

http://ciat-library.ciat.cgiar.org/articulos_ciat/2015/12620.pdf

www.grainscanada.gc.ca/en/

https://entomology.ca.uky.edu/ef145

http://www.fao.org/3/t1838e/T1838E00.htm#Contents

https://www.agric.wa.gov.au/pest-insects/insect-pests-stored-grain

Course Title with Credit Load
Ph.D. in Seed Science and Technology (SST)

Course Code	Course Title	Credit Hours
SST 601*	Hybrid Seed Production Technology	3 (2+1)
SST 602	Organic Seed Production	2 (1+1)
SST 603	Physiology and Biochemistry of Seeds	2 (1+1)
SST 604*	Genetic Purity and DUS Testing	3 (2+1)
SST 605	Seed Vigour and Crop Productivity	2 (1+1)
SST 606*	Advances in Seed Science	2 (2+0)
SST 607	Advances in Seed Quality Enhancement	2 (1+1)
SST 608	Germplasm Conservation Techniques	2 (1+1)
SST 609	Seed Ecology	2 (1+1)
SST 610	Seed Planning, Trade and Marketing	2 (1+1)
	Major Courses (Minimum 12 credits from above courses including *marked Courses)	12
	Minor Courses	06
	Supporting Courses	05
SST 691	Seminar I	01
SST 692	Seminar II	01
SST 699	Research	75
	Total Credits	**100**

Comprehensive (Pre-qualifying) Examination (Non-credit of 100 marks) Satisfactory/ Not satisfactory

*Compulsory Major Courses

Course Contents
Ph.D. in Seed Science and Technology (SST)

I. Course Title : Hybrid Seed Production Technology*
II. Course Code : SST 601
III. Credit Hours : 3 (2+1)

IV. Why this course?

Indian seed industry is dominated by hybrid seeds. Hybrid seed production requires scientific specialized skills and knowledge. Hence, it is necessary to impart knowledge to the students on hybrid seed production techniques and scientific principles involved in hybrid seed production of various crops.

V. Aim of the course

To provide students a comprehensive knowledge and practical exposure on hybrid seed production techniques in agricultural and horticultural crops.

VI. Theory

Unit I

Introduction – history – scope – importance of hybrid development – national and international scenario of seed industry – popular public sector hybrids in various crops. Heterosis – definition – expression – types – utilization of heterosis in hybrid development, hybrid vigour and seed vigour.

Unit II

Types of hybrids – intra-specific, inter-specific hybrids, single, double, three way cross, top cross hybrids – apomixes; generation system of seed multiplication in different types of hybrids. Development and maintenance of inbred lines – male sterile – maintainer lines – fertility restoration – transgenic hybrids – principles and method of development.

Unit III

Breeding tools – genetic mechanism – male sterility – types: CMS, GMS, CGMS, TGMS, PGMS – barnase and barstar system – pistillateness – self incompatibility. Manual creation of male sterility – emasculation and pollination – gametocides – mode of action, mechanism. Synchronization of flowering – problems – methods to achieve synchrony – planting ratio and supplementary pollination methods.

Unit IV

Techniques of hybrid seed production in major agricultural crops – cereals (wheat, rice), millets (maize, sorghum, bajra), pulses (red gram), oilseeds (sunflower, castor, mustard), cotton and forage crops.

Unit V

Hybrid seed production techniques in horticultural crops – tomato, brinjal, chilli, bhendi, onion, bitter gourd, bottle gourd, ridge gourd, cucumber, melon, cabbage, cauliflower, potato, coconut and papaya.

VII. Practical

- Characteristics features of parental lines and their hybrids;
- Floral biology of rice, maize, pearlmillet, sunflower, castor and cotton;
- Study on floral biology of vegetable crops – solanaceous and other vegetables;
- Study on floral biology of cucurbitaceous crops;
- Production and maintenance of A, B and R lines;
- Practicing planting design and border rows – rice, maize, pearlmillet, sunflower and red gram; brinjal and chillies;
- Practicing planting design and border rows in tomato, cotton and cucurbitaceous vegetables;
- Manipulation for synchronization – rice, sunflower, pearlmillet and sorghum;
- Practicing supplementary pollination – rice and sunflower;
- Practicing field inspection in hybrid seed production plot – crops planted in ratio – sunflower, pearlmillet, sorghum, etc.;
- Practicing field inspection in hybrid seed production field – red gram, castor, cotton, cucurbits and tomato;
- Practicing roguing and identification of off-types – pollen shedders – shedding tassel – selfed fruits;
- Visit to hybrid seed production fields;
- Visit to potato seed production plots;
- Determination of cost benefit of hybrid seed production;
- Visit to seed Industry and assessing problems and perspectives in hybrid seed production.

VIII. Teaching methods

- Classroom lectures
- Power point presentation
- Student assignment and presentation
- Demonstration
- Field visits

IX. Learning outcome

By learning this course, students will acquire a comprehensive knowledge and practical skills on hybrid seed production techniques both in agricultural and horticultural crops.

X. Suggested Reading

Agarwal RL. 2012. *Seed Technology*. 3rd Ed. Oxford & IBH Publishers, New Delhi.

Basra A. 1999. *Heterosis and Hybrid Seed Production in Agronomic Crops*. CRC Press., Florida, United States.

Chhabra AK. 2006. *Practical Manual of Floral Biology of Crop Plants*. Department of Plant Breeding, CCSHAU, Hisar.

Dar SH. 2018. *Methods of Hybrid Seed Production in Major Crops*. Educreation Publishing, Chhattisgarh.

Frankel R and Galun E. 1977. *Pollination Mechanisms*, Reproduction and Plant Breeding. Springer Verlag, New York.

Hebblethwaite PD. 1980. Seed Production. Butterworth Heinemann Ltd., London, UK.

Joshi AK and Singh BD. 2004. *Seed Science and Technology*. Kalyani Publishers, New Delhi.

Krishnan M. 2012. *Plant breeding and Hybrid Seed Production*. Domin and Publishers & Distributors, New Delhi, India.

Kulkarni GN. 2011. *Principles of Seed Technology*. Kalyani Publishers, New Delhi.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur, India.

McDonald MF and Copeland LO. 2012. *Seed Production: Principles and Practices*. Springer Science and Business Media, Boston, United States.
Mondal SS, Saha M and Sengupta K. 2009. *Seed Production of Field Crops*. New India Publishing Agency, New Delhi.
Sen S and Ghosh N. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi.
Singhal NC. 2003. *Hybrid Seed Production*. Kalyani Publishers., New Delhi, India.
Singhal NC. 2003. *Hybrid Seed Production in Field Crops*. Kalyani Publications, New Delhi.
Singhal NC. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.
Vanangamudi K, Prabhu M, Kalaivani S, Bhaskaran M and Manonmani V. 2010. *Vegetable Hybrid seed Production and Management*. Agrobios., Jodhpur, India.

XI. Suggested e-books

https://www.springer.com/in/book/9780792373223
https://www.springer.com/in/book/9780412075513
https://www.nipabooks.com/info/9788190723763/seed-production-of-field-crops
https://www.kopykitab.com/Vegetable-Hybrid-Seed-Production-And-Management
https://www.researchgate.net/publication/229432295_Hybrid_Seed_Production_ and_Flowers
http://www.worldcat.org/title/seed-production-principles-andractices/oclc
https://libgen.is/search.php?req=Raymond+A++T+George&column=author
https://libgen.is/search.php?req=Raymond%20A%20%20T%20George&column[]= author
https://www.researchgate.net/profile/Gulzar_S_Sanghera/publication/236865752_ Advances_in_Hybrid_Rice_Technology_through_Applications_ of_Novel_Technologies/links/0deec519b46087d815000000.pdf

XII. Suggested websites

www.agriquest.info
www.agriinfo.in
www.seedquest.com
https://agriinfo.in/botany/18/
http://www.fao.org/3/a-e8935e.pdf
http://www.agriquest.info/seed_production.php
http://agritech.tnau.ac.in/seed_certification/seedtech_index.html

I. Course Title : Organic Seed Production
II. Course Code : SST 602
III. Credit Hours : 2 (1+1)

IV. Why this course?

After ascertaining the food security, the present day agriculture is moving towards quality farm produces, hence organic agriculture is getting momentum. The growing demand for organically produced farm produces among the consumers warrants more area under organic agriculture. Hence, organic agriculture needs the seeds which are produced organically and there is great scope for organic seed production.

V. Aim of the course

To make students to understand the concept of organic farming, principles and practices of organic seed production, certification and marketing.

VI. Theory

Unit I

Organic farming – definition, genesis, concepts and principles; importance of organic farming and organic seed; organic seed – strategies, problems and perspectives – organic seed vs conventional seed; organic seed production – factors influencing seed production – soil health – GMO elements of seed.

Unit II

Techniques of organic seed production – selection of land – pre requisite for seed production – conversion period – soil amendments – green manures; multi-varietal seed techniques – organic sources of manures – bulky, concentrated and liquid manures, biofertilizers and biocontrol agents – organic seed treatment.

Unit III

Organic weed management practices – manual and mechanical methods – mulching – thermal weed control; growth promoting substances – *panchakavya*, fish amino acid, etc.; organic plant protection measures – herbal insecticides – IPM strategies; post harvest techniques – drying, processing and grading; organic seed treatment and storage.

Unit IV

Organic certification application – registration – verification of records; organic seed certification – tagging; role of organizations in production and marketing of organic seed – national and international organizations involved – public, private – NGOs – International Federation of Organic Agriculture Movement (IFOAM) – basic standards and EU regulations – organic seed marketing.

Unit V

Crop specific organic seed production and post harvest seed management techniques for major food crops, vegetables and fruit crops – economics of organic seed production and demand for organic seed.

VII. Practical

- Studying the field and seed standards for organic seed production;
- Collection and identification of organic manures and liquids;
- Preparation of organic products for soil application;
- Preparation of *panchakavya*, starter solutions and vermiwash;
- Organic priming of seeds with *panchakavya* and vermiwash;
- Preparation of leaf extracts and starter solutions and preparation of organic products for foliar application;
- Studying the effect of organic nutrients and foliar sprays on seed quality;
- Preparation of organic products for seed treatment and studying the effect on seed quality;
- Assessing the storage behaviour of organically treated seeds;
- Selection of suitable container and dry leaves or shrubs for enhanced storability;
- Organic treatment for management of seed health;
- Production and assessment of bio control agents for effective pest control;
- Economics of organic seed production and assessing demand;
- Visit to organic farm and seed production field;
- Visit to Department of organic certification;
- Visit to organic retail shops.

VIII. Teaching methods

- Classroom lectures
- Group assignments and presentation
- Laboratory and field experiments
- Demonstration
- Field visits

IX. Learning outcome

After completion of this course, students will gain knowledge, skill and confidence to take up organic seed production for sustainable agriculture.

X. Suggested Reading

Bryan Connolly B, Langer J and Lawn CR. 2011. *Organic Seed Production and Saving: The Wisdom of Plant Heritage*. Chelsea Green Publishing, Vermont, USA.

Gehlot D. 2010. *Organic Farming: Components and Management*. Agrobios., Jodhpur, India.

Gehlot D. 2012. *Organic Farming: Standards, Accreditation, certification and Inspection*. Agrobios., Jodhpur, India.

Panda SC. 2012. *Soil Management and Organic farming*, Agrobios., Jodhpur, India.

Panda SC. 2013. *Principles and Practices of organic Farming*. Agrobios., Jodhpur, India.

Suresh N and Deshmukh. 2010. *Organic Farming: Principles, Prospects and Problems*. Agrobios., Jodhpur, India.

White JM. 1995. *Organic Vegetable Production*. UF/IFAS Coop. Ext. Serv., HS720., Florida, United States.

XI. Suggested e-books

https://ufdcimages.uflib.ufl.edu/IR/00/00/33/80/00001/HS22700.pdf
https://www.ifoam.bio/en/organic-landmarks/principles-organic-agriculture
www.apeda.gov.in/apedawebsite/organic/organic.../english_organic_sept05.pd
https://ncof.dacnet.nic.in/Training./Training...in/Cert_and_Inspection_ manual.pdf
https://www.ebooks.com/en-us/96381019/organic-seed-production-and-saving/ bryan-connolly-jocelyn-langer-c-r-lawn/

XII. Suggested website

www.tnocd.net
https://www.sare.org/
https://www.ifoam.bio/
http://www.ncof.dacnet.nic.in
http://edis.ifas.ufl.edu/CV118
www.harrismoran.com/technology/default.htm
https://attra.ncat.org/attra-pub-summaries/?pub=70
http://www.harrismoran.com/technology/default.htm
https://www.academia.edu/4601825/Organic_seed_production
http://www.cals.ncsu.edu/sustainable/peet/IPM/diseases/org_cert.html
https://www.sare.org/Learning-Center/Topic-Rooms/Organic-Production/Organic-Seeds

I. Course Title : Physiology and Biochemistry of Seeds
II. Course Code : SST 603
III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed is a biological entity and the seed contains all micro and macro nutrients in the form of stored food, toxic compounds and secondary metabolites. Seeds are accumulated with these materials during development and maturation and it gets depleted during deterioration and storage. The developing seed embryo attains capacity to produce a new plant by utilizing these resources. Understanding the mechanism of accumulation of food reserves and pattern of its utilization during germination will enable the students to take up research on seed dormancy, germination and quality enhancement.

V. Aim of the course

To provide insight knowledge on physiological and biochemical events governing seed quality and itsurvival.

VI. Theory

Unit I

Seed development and maturation – role of cell organelles – embryogeny – translocation of assimilates – synthesis of starch, protein, lipid, secondary metabolites and toxic compounds – possible alteration in metabolic pathway.

Unit II

Development of embryo, endosperm and seed coat – translocation of assimilates and food reserves; desiccation tolerance – mechanism, hypothesis, role of LEA proteins; development of hard seeds – mechanisms and factors.

Unit III

Seed dormancy – types – physiology and biochemistry of seed dormancy induction and release – hormonal regulation of seed dormancy – environmental control – genetic inheritance and control of dormancy; physiology of orthodox, recalcitrant and intermediate seeds.

Unit IV

Seed germination – acquisition of viability and capacity of germination during development – genetics of germination acquisition; types of germination – phases of germination – requirements – imbibition – enzyme activation and hormonal regulation – respiration – mitochondrial activity and ATP synthesis – protein and nucleic acid synthesis – metabolism of starch, protein, lipid – physiology of embryo growth and development.

Unit V

Seed deterioration – theories, causes – ultra-structural, cell membrane and functional changes; biochemical changes – enzyme activity, storage reserves and genetic changes; lipid peroxidation – biological effects – free radicals and secondary products.

VII. Practical

- Study on the pattern of seed development and maturation;
- Study on the structural changes during seed maturation;
- Estimation of seed moisture content, fresh and dry weight and acquisition of germination and dormancy;
- Estimation of different hormones during seed development and maturation – GA and ABA;
- Estimation of phenolic compounds during seed maturity;
- Estimation of food reserves accumulation – starch, protein and oil at different stages of maturity;
- Study on the pattern of seed development in recalcitrant seeds;
- Studying the germination behaviour of different type of seeds;
- Study on imbibition pattern and soaking injury in seeds;
- Estimation of enzymes in dormant and non-dormant seeds;
- Estimation of hormones in dormant and non-dormant seeds;
- Studying the effect of light and temperature on dormancy;
- Study on deterioration pattern of orthodox and recalcitrant seeds;

- Estimation of lipid peroxidation product and free fatty acid;
- Studying the cytological and chromosomal changes in deteriorated seeds;
- Estimation of volatile aldehydes during seed storage and deterioration.

VIII. Teaching methods

- Classroom lectures
- Assignments and presentations
- Field and laboratory experiments

IX. Learning outcome

Completion of this course will enable the students to understand the mechanism of seed development, regulation of dormancy, germination and deterioration and help them to understand the mysteries in seed to address the problems in quality seed production and storage.

XI. Suggested Reading

Barton LV. 1961. *Seed Preservation and Longevity*, (Vol. 1). Leonard Hill, London.

Baskin C and Baskin JM. 2014. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Academic Press, Cambridge, UK.

Bewley JD and Black M. 1982. *Physiology and Biochemistry of Seeds in Relation to Germination* (Vol. I & II). Springer Verlage, Berlin Heldelberg, New York, United States.

Bewley JD, Bradford KJ, Hilhorst HWM and Nanogaki H. 2013. *Seeds: Physiology of Development*, Germination and Dormancy. Springer, New York.

Bradbeer JW. 1988. *Seed Dormancy and Germination*. Chapman and Hall, New York, USA.

David R Murray. 1985. *Seed Physiology*. Volume 2: Germination and Reserve Mobilisation. Academic Press, London, UK.

Justice OL and Bass LN. 1978. *Principles and Practices of Seed Storage*. Agriculture Hand Book No. 506, Castle House Publication Ltd., Washington.

Khan AA. 1977. *Physiology and Biochemistry of Seed Dormancy and Germination*. North Holland Co, Amsterdam, New York, United States.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur, India.

Mayer AM and Mayber AP. 1989. *Germination of Seeds*. Pergamon Press, Oxford, United kingdom.

Ovcharov KE. 1977. *Physiological Basis of Seed Germination*, Amerind Publishing Co,New Delhi and New York, United States.

Prakash M. 2011. *Seed Physiology of Crops*. Satish Serial Publishing house. Azadpur. New Delhi.

Roberts EH. 1972. *Viability of seeds*. Springerlink, New York, USA.

Vanangamudi K. 2006. *Seed Physiology*. Associated Publishing Company, New Delhi, India.

XI. Suggested e-books

http://agris.fao.org/agris-search/search.do?recordID=US201300553998

http://www.worldcat.org/title/physiological-basis-of-seed-germination-fiziologicheskie-osnovy-vskhozhesti-semyan/oclc/19369598

https://www.springer.com/in/book/9783642686450

https://link.springer.com/chapter/10.1007/978-1-4615-1747-4_2

https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/desiccation-tolerance

https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/embryogenesis

https://www.cell.com/current-biology/comments/S0960-9822(17)30562-6

https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1365-3040.2012.02542.x

https://dl.sciencesocieties.org/publications/books/pdfs/cssaspecialpubl/physiologyofsee/frontmatter

XII. Suggested websites

http://www.seedbiology.de/dormancy2.asp
http://www.seedbiology.de/dormancy.asp
https://www.ncbi.nlm.nih.gov/pubmed/22620982
https://www.britannica.com/science/germination
http://sbc.ucdavis.edu/Research_pages/Seed_physiology_and_technology/
http://www.biologyreference.com/Re-Se/Seed-Germination-and-Dormancy.html
https://www.intechopen.com/books/advances-in-seed-biology/seed-dormancy
https://courses.lumenlearning.com/wm-biology2/chapter/development-seeds-fruit
www.iari.res.in/index.php?option=com_content&view=article&id=449 &Itemid=137

I. Course Title : Genetic Purity and DUS Testing*

II. Course Code : SST 604

III. Credit Hours : 3 (2+1)

IV. Why this course?

Genetic purity of seeds is one of the most important basic quality characters as per Seeds Act 1966. Loss of genetic purity leads to varietal deterioration leads to elimination of variety from seed supply chain. After establishment of PPV and FRA, varietal purity is assessed by using established DUS characters and guidelines. Human resource on methods of genetic purity assessment and DUS characters is much essential to prevent variety deterioration as well as for protection of plant varieties.

V. Aim of the course

To impart knowledge on various methods of genetic purity assessment and DUS testing for protection of plant varieties.

VI. Theory

Unit I

Genetic purity – importance – factors influencing genetic purity; genetic/ cultivar purity test – objectives – principles – methods; laboratory tests – green house and field plot methods, grow – out test, seed and seedling growth tests; chemical and biochemical methods; anthocyanin pigmentation, secondary compounds, phenol, peroxidase and fluorescence tests – chromatography techniques.

Unit II

Electrophoretic analysis of proteins and isozymes; DNA finger printing methods – RAPD, AFLP, SSR, SNP and other markers; computer based machine vision technique and image analysis for varietal identification.

Unit III

Genesis of Plant Variety Protection (PVP); International Union for Protection of New Varieties of Plants (UPOV) and its functions – GATT agreement in relation to plant variety protection; Protection of Plant Varieties and Farmer's Rights (PPV and FR) Act 2001 – objectives, salient features, farmer's rights, breeder's rights, researcher's rights – PPV and FRA Rules 2003.

Unit IV

Criteria for protection of new varieties of plants; Distinctness, Uniformity and Stability (DUS) testing – principles and procedures, guidelines, sample size, test duration, testing option; varieties of common knowledge – extant variety – essentially derived variety – collection of reference samples – grouping of varieties – example varieties; types and categories of characters – recording observations on characteristics – colour characteristics.

Unit V

Assessment of DUS characters of major crops based on morphological, biochemical and molecular markers – rice, maize, wheat, barley, black gram, green gram, red gram, cowpea, rajma, sunflower, groundnut, castor, mustard, tomato, brinjal, onion, potato, chilli, bhendi, cucurbits, cole crops, sugarcane, cotton, flower, fruit and tree species; statistical procedure – computer software for DUS testing; guidelines for registration of germplasm – impact of plant variety protection on seed industry growth.

VII. Practical

- Genetic purity assessment based on seed characters;
- Genetic purity assessment based on seedling growth tests, anthocyanin pigmentation;
- Genetic purity assessment based on secondary compounds, phenol, peroxidase and fluorescence tests;
- Chromatography analysis of secondary compounds;
- Electrophoretic analysis of seed protein and isozymes;
- DNA fingerprinting using PCR techniques;
- DUS testing based on morphological descriptors of plant – rice and millets;
- DUS testing based on morphological descriptors of plant – pulses and oil seeds;
- DUS testing based on morphological descriptors of plant – vegetable crops;
- DUS testing based on morphological descriptors of plant – flower, fruit and tree species;
- Recording observations and interpretation of data;
- Tree method of classification of varieties/ cultivars;
- Chemical and biochemical test applicable for DUS testing;
- Practical exercise on recording DUS characteristics, statistical analysis and interpretation in major agricultural crops;
- Practical exercise on recording DUS characteristics, statistical analysis and interpretation in major horticultural crops;
- Visit to DUS test centers.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Field and laboratory experiments
- Demonstration
- Field visits

IX. Learning outcome

After completion of this course, the students will gain knowledge on the methods of assessing genetic purity and able to distinguish varieties based on DUS characters.

X. Suggested Reading

Anon. 2016. *Manual of Seed Certification Procedures*. Directorate of Seed Certification, Coimbatore, Tamil Nadu.

Chakrabarthi SK. 2010. *Seed Production and Quality Control*. Kalyani Publishers, New Delhi.

Choudhary DR. 2009. *Guidelines for Storage and Maintenance of Registered Plant Varieties in the National Gene Bank*. Published by Protection of Plant Varieties and Farmer's Rights Authority. Ministry of Agriculture, GoI, New Delhi, India.

ISTA. 2010. *Handbook of Variety Testing*. International Seed Testing Association, Switzerland.

Joshi AK and Singh BD. 2004. *Seed Science and Technology*, Kalyani Publishers, New Delhi, India.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur, India.

Mishra DK, Khare D, Bhale, MS and Koutu GK. 2011. *Handbook of Seed Certification.* Agrobios, Jodhpur, Rajasthan.

Ramamoorthy K, Sivasubramaniam K and Kannan M. 2006. *Seed Legislation in India*. Agrobios, Jodhpur, Rajasthan.

Trivedi PC. 2011. *Seed Technology and Quality Control*. Publications, Jaipur, Rajasthan.

XI. Suggested e-books

https://books.google.co.in/books?isbn=16118603932.
https://books.google.co.in/books?isbn=81894220303.
https://books.google.co.in/books?id=2FbwZwEACAAJ
https://books.google.co.in/books?id=J5bQtgAACAAJ
https:/books.google.co.in/books?isbn=0851997392
https://www.upov.int/edocs/tgdocs/en/tg023.pdf

XII. Suggested websites

www.seedquest.com
www.ucanr.edu
www.sasa.gov.uk
www.ppvfra.org
https://www.upov.int/test_guidelines/en/
http://plantauthority.gov.in/crop-guidelines.htm
https://www.upov.int/resource/en/dus_guidance.html
https://www.upov.int/edocs/tgpdocs/en/tgp_6_section_2.pdf
https://www.upov.int/publications/en/tg_rom/introduction.html

I. Course Title : Seed Vigour and Crop Productivity
II. Course Code : SST 605
III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed vigour is an important quality parameter needs to be assessed to estimate the real planting value of seed. Seed vigour is governed by several factors which ultimately decide the crop productivity and yield. Hence, knowledge on the concept of seed vigour and its manifestations, prediction of seed vigour in relation to crop productivity will be useful for better management of seed lots and seed crop.

V. Aim of the course

To impart knowledge on seed vigour, vigour test, impact of seed vigour on seed production, storage and seed management.

VI. Theory

Unit I

Seed vigour – importance, concepts, definitions, vigour *vs* viability, historical development – ISTA vigour committee. Factors influencing seed vigour – genetic, agronomic, biotic and abiotic factors.

Unit II

Seed vigour and senescence – sequence of vigour loss – manifestations of seed vigour – physical, physiological, biochemical and molecular manifestations; vigour in relation to seed dormancy and germination; vigour in relation to value for cultivation and use.

Unit III

Vigour tests – history – definition – characteristics – types – direct and indirect tests – physical test – x-ray radiography, seed size; physiological test – seedling first count, radicle emergence, speed of germination, seedling measurement; stress tests – brick gravel test, cool test, cold test, paper piercing test, ethanol, ammonium chloride and NaCl soak tests, accelerated ageing test, exhaustion test, controlled deterioration test, osmotic stress test.

Unit IV

Chemical and biochemical tests – electrical conductivity test, free sugars and amino acids, tetrazolium chloride test, respiration quotient, GADA test, free fatty acid, DPPH, respiratory and hydrolytic enzymes tests, modern vigour tests – machine vision, Q_2 analyzer – standardization of vigour test.

Unit V

Influence of seed vigour – crop growth, field emergence, productivity and storage; vigour of vegetative propagules; role of seed vigour in field emergence, crop growth, yield and productivity. Seed vigour improvement and management techniques – pre-sowing and pre-storage – mid storage methods to improve seed vigour.

VII. Practical

- Collection and evaluation of germination of seed lots with different vigour status;
- Evaluation of seed vigour by physical vigour test – seed size, colour, weight – turbidity test;
- Evaluation of seed vigour by physiological vigour test – imbibition pattern, speed of emergence, radicle emergence, germination, seedling measurement and computation of various index;
- Conducting different stress tests – brick gravel and paper piercing tests;
- Conducting accelerated ageing and controlled deterioration test;
- Conducting chemical stress test – NH_4Cl, NaCl, mannitol, PEG test;
- Special vigour tests – cool germination test – cold test – anaerobic test;
- Biochemical vigour test – electrical conductivity, free sugars and amino acid test in seed leachate;
- Estimation of dehydrogenase enzyme activity;
- Estimation of free fatty acids in seed lots in varying vigour levels;
- Bio-assay test for seed vigour;
- Estimation of volatile aldehydes in different crop seeds with varying vigour;
- Correlation studies between field emergence and different vigour tests;
- Seed vigour on field establishment, population maintenance and crop growth and productivity;
- Pre-sowing vigour management techniques;
- Pre-storage and mid storage vigour management techniques.

VIII. Teaching methods

- Classroom lectures
- Assignment and presentation
- Slides/ video shows

- Practical exercise
- Hands on training

IX. Learning outcome

This course will enable the students to understand the concept of seed vigour and enhance the analytical skills to predict and assess the vigour accurately so as to adjust the seed lots for its value for cultivation and usage.

X. Suggested Reading

Agrawal PK and Dadlani M. 1992. *Techniques in Seed Science and Technology*. 2nd Ed. South Asian Publications.
Bewley J and Black M. 1994. *Physiology of Development and Germination*. Springerlink, New York.
Chakrabarthi SK. 2010. *Seed Production and Quality Control*. Published by Kalyani Publisher., New Delhi, India.
Chalam GV, Singh A and Douglas JE. 1967. *Seed Testing Manual*. ICAR and United States Agency for International Development, New Delhi.
David R Murray. 1985. *Seed Physiology*. Saunders College Publishing/ Har court Brac.
International Seed Testing Association. 2018. *Handbook on Seedling Evaluation*, 4th Edition, Published by ISTA, Zurichstr, Switzerland.
ISTA. 1999. *Seed Science and Technology*, 27th supplement.
Khan AA. 1977. *The Physiology and Biochemistry of Seed Dormancy and Germination*. North–Holland Publishing Company, USA.
Kulkarni GN. 2011. *Principles of Seed Technology*. Kalyani Publishers, New Delhi, India.
Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of post harvest seed physiology and technology*. Agrobios., Jodhpur, India.
Mayer AM and Mayber AP. 1963. *Germination of Seeds*. Pergamon Press, Oxford, New York.
Roberts EH. 1972. *Viability of Seeds*. Springerlink, New York.
Sen S and Ghosh N. 2010. *Seed Science and Technology*. Kalyani Publishers., New Delhi, India.
Singhal NC. 2010. *Seed Science and Technology*. Kalyani Publishers, New Delhi, India.
Trivedi PC. 2011. *Seed Technology and Quality Control Pointer Publications*., Jaipur, India.
Vasudevan SN, Doddagowder SR, Rakesh CM and Patil SB. 2013. *Seed Testing and Quality Control*. Agrotech Publications, Udaipur, Rajasthan.

XI. Suggested e-books

https://link.springer.com/chapter/10.1007/978-94-009-2764-3_71
https://link.springer.com/chapter/10.1007/978-1-4684-7747-4_8
https://link.springer.com/chapter/10.1007/978-1-4615-1783-2_7
https://doi.org/10.1079/9780851993959.0073
https://www.researchgate.net/publication/326255175_Seed_Vigour_Testing_ Principland_Methods
https://www.springer.com/in/book/9789400956872
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4233836/
https://link.springer.com/chapter/10.1007/978-1-4615-1783-2_8
http://www.worldcat.org/title/techniques-in-seed-science-and-technology/oclc/600 47727
http://wrap.warwick.ac.uk/74767/1/WRAP_0380014-lf-271115-revised_darwin_ review_for_submission_.pdf

XII. Suggested websites

www.ista.org.in
www.cambridge.org
www.tandfonline.com
www.seednet.gov.in
www.seedtest.org
https://academic.oup.com/jxb/article/67/3/567/2893341

http://www.scielo.br/pdf/sa/v72n4/0103-9016-sa-72-4-0363.pdf
https://www.researchgate.net/publication/284279769_Seed_vigour_and_ crop_establishment_Extending_performance_beyond_adaptation
https://www.semanticscholar.org/paper/Seed-vigour-and-crop-establishment%3A -extending-Finch-Savage-Bassel/a5af7beae17bd31058db0f645edd647cbb9e 9c2b

I. Course Title : Advances in Seed Science*

II. Course Code : SST 606

III. Credit Hours : 2 (2+0)

IV. Why this course?

Seed science is the study of seeds from its development to storage. The seed science is interdisciplinary and is closely connected with botany, physiology, biochemistry and genetics. Exposing students to advanced and recent developments in seed science and technology will enable them to take up interdisciplinary advance research.

V. Aim of the course

To impart knowledge on the recent developments in various frontier areas of seed science and their application in seed technology.

VI. Theory

Unit I

Physiological and molecular aspects of seed development – gene expression during seed development – selective elimination of cells – theories and concepts; physiological and molecular regulation of germination and dormancy; desiccation and stress tolerance – gene expression – mechanism – structural changes in membranes of developing seeds; prediction of seed dormancy and seed longevity using mathematical models; climate change effects on pollination, seed formation, development and quality.

Unit II

Recent techniques in seed production of self incompatible, protogyny, protandry and apomictic plant species – Gene Use Restriction Technology (GURT) – terminator and verminator technology – Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) *Cas* – gene editing; seed proteomics – principles, methods, applications in seed science- genetic analysis and QTL mapping of traits related to seed vigour, ageing and longevity – OMICS in related to seed science and technology; somatic embryogenesis – principles and methods of production of synthetic/ somatic seeds – merits and demerits.

Unit III

Modern techniques for identification of varieties and hybrids – principles and procedures; DNA fingerprinting and other molecular techniques and their utilization – GM seeds and their detection techniques; Use of machine vision and image analysis techniques for varietal identification. Application of artificial intelligence (AI) and machine learning (ML) and virtual reality (VR) in seed science.

Unit IV

Recent accomplishments in seed enhancement research – seed coating, pelleting and priming techniques – physiological, molecular and sub-cellular basis of seed priming – detection and identification of seed borne diseases and insect pests through advanced techniques – ELISA and PCR based techniques.

Unit V

International movement of seeds – OECD seed certification schemes – recent developments in seed laws and policies – ethical issues and IPR system related to seed trade and movement.

VII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignment and presentations

VIII. Learning outcome

After completion of this course the students will be able to take up research on seed biotechnology.

IX. Suggested Reading

Baskin C and Baskin JM. 2014. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Academic Press, Cambridge, UK.

Benech-Arnold R and Rodolfo S. 2004. *Handbook of Seed Physiology: Applications to Agriculture*. CRC Press., Florida, United States.

Bewley JD and Black M. 1994. *Seeds: Physiology of Development and Germination*. Springer, New York, USA.

Bewley JD, Bradford KJ, Hilhorst HWM and Nanogaki H. 2013. *Seeds: Physiology of Development, Germination and Dormancy*. Springer, New York.

Black M and Bewley JD. 2000. *Seed Technology and its Biological Basis*. CRC Press. Florida, United States.

David R Murray. 1985. *Seed Physiology*. Volume 2: Germination and Reserve Mobilisation. Academic Press, London, UK.

Figeys D. 2005. Industrial Proteomics: Applications for Biotechnology and Pharmaceuticals (No. TP248. 65. P76 I535 2005). United States.

Kozlowski TT. 2012. *Seed Biology: Importance, Development and Germination*. (Vol. I). Academic Press Inc., New York.

Lombardo L. 2014. Genetic Use Restriction Technologies: a review. *Plant biotechnology journal*. **12**(8): 995-1005.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur, India.

Nicolas G, Bradford KJ, Come D and Pritchard HW. 2003. *The Biology of Seeds: Recent Research Advances*. Proceedings.

Patterson SD and Aebersold RH. 2003. Proteomics: the first decade and beyond. Nature genetics. **33**(3s): 311.

Rakshit A and Singh HB. 2018. *Advances in Seed Priming*. Springer Nature Singapore Ltd., Singapore.

Redenbaugh K. 1993. *Synseeds: Application of Synthetic Seeds to Crop Improvement*. CRC Press, London, UK.

X. Suggested e-books

https://www.springer.com/gp/book/9783540574484

https://www.synthego.com/resources/crispr-101-ebook

https://link.springer.com/book/10.1007/978-981-13-0032-5

https://www.springer.com/gp/book/9780306447471#aboutBook

https://link.springer.com/chapter/10.1007/978-1-4615-1619-4_13

https://www.cambridge.org/core/journals/experimental-agriculture/article/biology-of-seeds-recent-research-advances-edited-by-g-nicolas-k-j-bradford-d-come-and-h-w-pritchard-wallingford-uk-cabi-international-2003-pp-472-9500-isbn-0851996 531/57DACB0A07CFD0246AAD11713540F1E6

https://www.researchgate.net/publication/240592094_Black_M_Bewley_JD_eds_ 2000_Seed_technology_and_its_biological_basis_419_pp_Sheffield_ Sheffield_Academic_Press_89_hardback

https://www.crcpress.com/Handbook-of-Seed-Physiology-Applications-to-Agricu lture/Benech-Arnold-Snchez/p/book/9781560229292

https://www.elsevier.com/books/seeds/baskin/978-0-12-416677-6

https://international.neb.com/tools-and-resources/feature-articles/crispr-cas9-and-targeted-genome-editing-a-new-era-in-molecular-biology

https://www.omicsonline.org/scholarly/seed-science-and-technology-journals-articles-ppts-list.php

https://libgen.is/book/index.php?md5=F63727B21E14953F0003168A2452B3FE

https://www.researchgate.net/publication/228621809_Techniques_for_detecting_ genetically_modified_crops_and_products

https://www.intechopen.com/books/new-challenges-in-seed-biology-basic-and-translational-research-driving-seed-technology/recent-advances-in-seed-enhancements

https://books.google.co.in/books/about/Advances_in_Seed_Priming.html?id= iBtfDwAAQBAJ&printsec=frontcover&source= kp_read_button&redir_esc= y#v=onepage&q&f=false

XI. Suggested websites

https://www.sbc.ucdavis.edu
https://www.seedbiotech.com
http://www.gmotesting.com/Testing-Options
https://www.ncbi.nlm.nih.gov/pubmed/25185773
https://www.oecd.org/agriculture/seeds/
https://www.addgene.org/crispr/guide/
https://www.yourgenome.org/facts/what-is-crispr-cas9
https://cban.ca/gmos/issues/terminator-technology/
https://www.nature.com/articles/s41598-017-08669-5
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5495694/
https://www.ias.ac.in/article/fulltext/reso/006/05/0039-0047
https://www.cell.com/action/showPdf?pii=S1360-1385%2807%2900038-6
https://www.sciencedirect.com/science/article/pii/S2215017X16301400
https://www.broadinstitute.org/what-broad/areas-focus/project-spotlight/questions-and-answers-about-crispr

I. Course Title : Advances in Seed Quality Enhancement
II. Course Code : SST 607
III. Credit Hours : 2 (1+1)

IV. Why this course?

Quality seed is a vital input for sustainable crop production and food security. Seed enhancement through various techniques can overcome germination constraints by uniform stands, earlier crop development and better yields. Understanding of the principles and mechanisms involved in seed quality improvement would enable to modulate the performance of seed in field.

V. Aim of the course

To impart knowledge on seed quality enhancement techniques and their associated quality changes in seed.

VI. Theory

Unit I

Seed quality – importance and enhancement – principles, concept, significance, strategies; types of seed enhancement – physical, physiological and biological enhancement techniques.

Unit II

Physical seed quality enhancement – concept and principles of grading – upgrading – magnetic, electromagnetic, irradiation, coating, pelleting, colouring; plasma treatment – thermal and cold plasma – treatment; application of nano formulations – concepts – principles – mode of action on improving germination.

Unit III

Physiological methods of seed quality enhancement – seed priming – principles, methods, mode of action – physiological, biochemical and molecular mechanism of priming techniques; seed infusion – principles and methods, mode of action – imparting abiotic stress tolerance – hardening – principles and methods.

Unit IV

Application of biological formulations – bacterial, fungal agents – concepts, formulations and compatibility; methods of application – growth promotion – protection – control over pest and disease infection and mode of action; designer/ smart seed – concept, methods, applicability to different crops.

Unit V

Effect of different treatments on crop establishment and modulation of seedling growth – crop geometry, phenology and yield improvement; storability of primed, coated and pelleted seeds – pre-storage and mid-storage enhancement techniques – hydration-dehydration techniques, moisture equilibrium drying and halogenations – principles, methods and application.

VII. Practical

- Physical seed quality up gradation – specific gravity separator, density grading, floatation technique;
- Practicing seed pelleting – methods of pelleting for different crop species;
- Performing seed coating – polymer, colouring and nano emulsion coating;
- Study on the effect of magnetic and electromagnetic seed treatment on seed germination and vigour;
- Practicing seed priming – hydro, osmo, halo and solid matrix priming methods;
- Nutrient and bio priming and assessing the performance of primed seeds;
- Assessing the storability of primed seed;
- Study on seed hardening on the performance of seed under abiotic stress;
- Preparation of designer/ smart seed for different crops;
- Biological seed treatment – biological formulations, bacteria, fungi, protectants and bio fertilizers;
- Study on the effect of biological seed treatment on seedling growth and disease incidence;
- Estimating the microbial population in biologically treated seeds;
- Assessing the storability and vigour potential of treated seeds;
- Performing mid-storage seed treatment – hydration-dehydration, moisture equilibrium and drying;
- Halogenation of seeds and their effect on seed performances;
- Assessing the performance of treated seeds under field condition.

VIII. Teaching methods

- Classroom lectures
- Student assignments and presentation
- Field and laboratory experiments
- Demonstration

IX. Learning outcome

This course enable the students to understand the mechanism of seed quality improvement, stress tolerance, population maintenance, crop geometry and yield improvement due to various enhancement techniques.

X. Suggested Reading

Bewley JD, Bradford KJ, Hilhorst HWM and Nonogaki H. 2013. *Seeds: Physiology of Development*, *Germination and Dormancy*, Third Edition. Springer, New York, United States.

Doijode SD. 2006. *Seed Quality in Vegetable Crops. In: Handbook of Seed Science and Technology*. Basra AS (Ed.). The Haworth Press, New York, United States. pp. 677–702.

Filatova I, Azharonok V, Lushkevich V, Zhukovsky A, Gadzhieva G, Spasic K, Zivkovic S, Puac N, Lazovic S, and Malovic G. 2013. *Plasma Seeds Treatment as a Promising Technique for Seed Germination Improvement*. 31st International Conference on Phenomena in Ionized Gases, Granada, Spain.

Glick BR. 2012. *Plant Growth-Promoting Bacteria: Mechanisms and Applications*. Hindawi Publishing Corporation, Scientifica.

Halmer P. 2003. 'Methods to improve seed performance.' In: Benech-Arnold RL, Sanchez RA (Eds.). *Seed Physiology, Applications to Agriculture*. Food Product Press, New York, United States.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur, India.

McDonald MF and Copeland LO. 2012. *Seed Production: Principles and Practices*. Springer Science and Business Media., Boston, United States.

Thomas B, Murphy DJ and Murray BG. 2003. *Encyclopedia of Applied Plant Sciences* (3 volume set). Elsevier Science, Netherland.

XI. Suggested e-books

https://www.springer.com/gp/book/9781461446927
https://link.springer.com/chapter/10.1007/978-1-4615-1619-4_13
https://www.intechopen.com/recent-advances-in-seed-enhancements
https://link.springer.com/content/pdf/bfm%3A978-981-13-0032-5%2F1.pdf
https://www.researchgate.net/publication/297732007_Advances_in_Seed_ Enhancements
https://www.researchgate.net/publication/309040118_Recent_Advances_in_Seed_ Enhancements
https://www.cambridge.org/core/journals/seed-science-research/article/seed enhancements/ 738B47B10C1C1B12C3D14D42E0B0A6C8
http://www.scientificpub.com/book-details/Seed-Quality-Enhancement-Principles-and-Practices-113.html

XII. Suggested websites

http://seedres.in/
http://agritech.tnau.ac.in/
http://www.bioline.org.br/pdf?cj17015
https://www.seedtest.org/en/home.html
www.niab.com/pages/id/24/Seed_Quality
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4109073/
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4746480/
https://content.ces.ncsu.edu/seed-and-seed-quality
http://greenpathindustries.com/plasma-seed-treatment/

I. Course Title : Germplasm Conservation Techniques

II. Course Code : SST 608

III. Credit Hours : 2 (1+1)

IV. Why this course?

Genetic resources are backbone for crop improvement. The tolerance of wild relatives to biotic and abiotic stress is gaining attention of plant breeders for transformation of genes. Hence, the young generation should be exposed to availability of various genetic resources and its conservation techniques for future use.

V. Aim of the course

To impart technical knowledge to students on the current issues and techniques of germplasm conservation for sustainable utilization in agriculture.

VI. Theory

Unit I

Biological diversity in India – importance – need for conservation – concept of natural reserves and gene banks; post-exploration handling of germplasm collections, preservation of seed and plant specimens, importance and use of herbaria; *in-situ* conservation – components – biosphere reserve – natural park; factors influencing conservation; *in-situ* conservation – national programmes – on farm conservation.

Unit II

Ex-situ conservation – components – plant genetic resources conservation in gene banks – national gene banks – gene repositories – seed gene bank – types of collections – base, active and working collections – *perma-frost* seed conservation – guidelines for sending seeds to gene bank; handling of orthodox and recalcitrant seeds for conservation – clonal repositories.

Unit III

Methods of *in-vitro* conservation – short, medium and long term, concept of active and base *in-vitro* genebank; *in-vitro* storage – culture maintenance – problems and perspectives – gene bank maintenance for temperate and tropical fruit crops, spices, tubers, bulbs, medicinal and aromatic plants; conservation of embryos and ovules, meristem, cell/ suspension cultures – protoplast and callus cultures – pollen culture – micro propagation techniques – genetic stability under long term storage.

Unit IV

Cryopreservation – principle and method – handling of orthodox and recalcitrant seeds for cryopreservation – cryoprotectants – desiccation, rapid freezing, slow freezing, vitrification techniques, encapsulation and dehydration techniques; application of cryopreservation techniques for agricultural, horticultural and forest crops.

Unit V

Gene bank standards for various crops – monitoring viability of stored seed samples – multiplication and regeneration of stored germplasm materials – National and International organizations – NBPGR and NPGRI – roll and functions; Dooms-day safe seed vault – Biodiversity International – conservation guidelines.

VII. Practical

- Study on *In-situ* conservation methods and case studies;

- Plant exploration, germplasm collection and documenting passport data;
- *Ex-situ* conservation techniques for long term conservation of germplasm collections;
- Preparation and handling of materials, packaging and documentation;
- Preparation of seed album and herbarium specimens for ex-situ conservation;
- Planning and designing of cold storage units and facilities for gene bank;
- Conservation protocols for orthodox seeds;
- Study of conservation protocols for recalcitrant seeds;
- Conservation techniques for vegetative propagules/ clones;
- Cryopreservation techniques – encapsulation, dehydration, freezing, thawing methods;
- Cryopreservation of *in-vitro* cultures – meristem, embryo, cell suspension and pollen cultures;
- Study on freezing and vitrification techniques;
- Conservation technique of forest tree species;
- Study on *in-vitro* cryo-genebanking and database management;
- Visit to national and regional seed gene banks;
- Visit to on-farm conservation sites and Botanical Survey of India.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentation
- Practical experiments
- Exposure/ field visits

IX. Learning outcome

This course will enable the students to understand the techniques of germplasm preservation and long term storage of gene pool and seeds.

X. Suggested Reading

Basra AS (Ed.). 1995. *Seed Quality: Basic Mechanisms and Agricultural Implications*. Food Product Press, USA.

Brush SB. 1999. *Genes in the field: On-farm Conservation of Crop Diversity*. Lewis Publishers, Boca Raton, Florida, USA.

Choudhary DR. 2009. *Guidelines for Storage and Maintenance of Registered Plant Varieties in the National Gene Bank*. Published by Protection of Plant Varieties and Farmer's Rights Authority. Ministry of Agriculture and Farmers Welfare, GoI, New Delhi.

Gupta D. 2009. *Seeds: Their Conservation Principles and Practices*. Sathish Serial Publishing House. New Delhi.

Jarvis DI, Meyer L, Klemick H, Guarino L, Smale M, Brown AHD, Sadiki M and Sthapit B. 2000. *A Training Guide for In-situ Conservation On-farm*. Version 1. International Plant Genetic Resources Institute, Rome, Italy.

Joshi AK and Singh BD. 2004. *Seed Science and Technology*, Kalyani Publishers, New Delhi.

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of Post Harvest Seed Physiology and Technology*. Agrobios., Jodhpur.

McDonald MF and Copeland LO. 2012. *Seed Production: Principles and Practices*. Springer Science and Business Media., Boston, USA.

Meerabi G and Pullaiah T. 2015. *Plant Biodiversity Conservation and Management*, Daya Publishing House, Delhi.

Rao NK, Hanson J, Dulloo ME, Ghosh K, Nowell A and larinde M. 2006. *Manual of Seed Handling in Genebanks*. Bioversity International, Rome.

Vernoy R, Shrestha P and Sthapit B. 2015. *Community Seed Banks: Origins, Evolution and Prospects*, Oxford, Routledge, UK.

XI. Suggested e-books

https://www.springer.com/gp/book/9783319225203
https://www.onlinelibrary.wiley.com/doi/10.1002/9781118316467.ch4
https://www.trove.nla.gov.au/work/10718000?q&versionId=12505038
http://www.libgen.io/book/index.php?md5=E4F14ADA7E2D7F05B1E7CA5C6EF F18E5
http://www.libgen.io/book/index.php?md5=ACEC8DC5834E84F9C13ACB780FA 760BC
http://www.libgen.io/book/index.php?md5=582A419EE2C82B58B98BFD7D856FDB91
http://www.libgen.io/book/index.php?md5=719F94827A8976F06BF2E6DC6FB9C093
http://www.cure.edu.uy/sites/default/files/04Libro%20Advances%2Bin% 2BPlant%202016.pdf
https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/germplasm-conservation
https://www.crcpress.com/Seed-Quality-Basic-Mechanisms-and-Agricultural-Implications/Gough/p/book/9781560228509
https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/Establishment_and_management_of_field_genebank_786.pdf

XII. Suggested websites

http://www.nbpgr.ernet.in/
http://www.bioversityinternational.org
http://www.nap.edu/read/2116/chapter/7
http://www.ncbi.nlm.nih.gov/pubmed/18080461
http://www.regjeringen.no/en/topics/food-fisheries-and-agriculture/svalbard-global-seed -vault/id462220/

I. Course Title : Seed Ecology

II. Course Code : SST 609

III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed is highly influenced by ecological situation in which the seed is produced. Seed also possess several adaptive mechanisms to escape from unfavourable environmental/ ecological situations. Study of underlying mechanisms and ecological significances of the seeds will be useful to the students to carryout research as well as production of quality seeds at different ecological conditions. This course also deals with the ecological strategies acquired by the seed for successful perpetuation.

V. Aim of the course

To study the influence of ecology on seed production, reproductive biology, seed dispersal, longevity and adoptation mechanisms and to study the effect of pollutants on seed production and quality.

VI. Theory

Unit I

Introduction to ecology – seed ecology – importance – genetic effects – geographic adaptation of native and invasive species; ecological factors on seed germination and regeneration; reproductive allocation – reproductive effort; flowering phenology, assessment of resource allocation – positional and azimuth influence on flowering and reproduction; influence of climate change on reproduction, seed formation, germination and dormancy.

Unit II

Seed dispersal – definition – modes of dispersal, dispersal dynamics, aerial seed dispersal, pre and post dispersal hazards, seed predators and ecological significance. Seed polymorphism – types, causes, consequences on seedling adaptation.

Unit III

Soil seed bank – definition – classification – soil seed bank dynamics. Thermodynamic models – population dynamics in soil seed bank – seed longevity and germination models in soil seed bank – weed seed ecology and longevity – long term experiments in buried seeds; ecological significance of seed dormancy and seed polymorphism.

Unit IV

Influence of environment on seed germination – allelopathy, temperature, light, moisture and gaseous environment – eco-physiological role in seed storage.

Unit V

Effect of pollutants – air, water and soil pollutants on seed germination and seedling establishment – factors limiting seedling establishment – problem soils and seed management techniques – climate change and seed production – management strategies to overcome the effect of climate change on seed production and germination.

VII. Practical

- Understanding flowering phenology of different crop species;
- Study of seed dispersal mechanism of different crop species;
- Study on agents and distance of dispersal of different crop species;
- Studies on pre and post dispersal hazards;
- Assessing the natural regeneration in relation to ecology;
- Assessing the problems related to natural regeneration;
- Experiment on naturally buried seeds – dormancy and longevity;
- Studies on effect of environmental factors on seed germination and dormancy;
- Influence of seed polymorphism on germination and dormancy;
- Assessing the allelopathy effect on seed germination in crop species;
- Effect of soil pollutants on seed germination;
- Effect of air pollutants on germination of crop seeds;
- Effect of water pollutants on growth on seed quality;
- Seed management practices for polluted environment and climate change effects;
- Visit to *in-situ* and *ex-situ* conservation sites;
- Visit to biological hotspots.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentation
- Practical experiments
- Exposure/ field visits

IX. Learning outcome

This course will make the students to understand the problems in natural regeneration, storage and dormancy and to address these problems.

X. Suggested Reading

Baskin CC and Baskin JM. 1998. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination*. Elsevier, Netherlands.

Fenner M and Ken Thompson. 2005. *The Ecology of Seeds*. Cambridge University Press, London, United Kingdom.

Heydecker W. (Ed.). 1985. *Seed Ecology*. Penn State University Press.
Kozolowski TT. 1972. *Seed Biology* Vol. II, Academic Press., New York and London.
Maiti RK, Sarkar NC and Singh VP. 2006 *Principles of Post Harvest Seed Physiology and Technology*. Agrobios, Jodhpur, India.
Sinclair TR and Gardner FP. 1977. *Principles of Ecology in Plant Protection*. CAB International, Wallingford, United Kingdom.

XI. Suggested e-books

https://www.springer.com/gp/book/9780412259302
https://www.cabi.org/bookshop/book/9781845936549
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2000770/
https://www.link.springer.com/chapter/10.1007/978-94-009-4844-0_4
http://www.libgen.io/book/index.php?md5=0CE8B3A7FC6224F8467E8D344B590741
http://www.libgen.io/book/index.php?md5=4AA6FDA278BAA40C1B47BA1EB9E8BC4
http://www.libgen.io/book/index.php?md5=31A06377ADC97C71831D82D4516A4DD7
http://www.libgen.io/book/index.php?md5=97028932B0E1278AE3BE17D231B41F23
http://www.ideal.egranth.ac.in/cgi-bin/koha/opacdetail.pl?biblionumber=116395&shelfbrowse_itemnumber=244623
http://fes.org.in/source-book/ecological-restoration-source-book.pdf?file=ZG93bmxvYWQvd3AxOS5wZGY=?file=ZG93bmxvYWQvd3AxOS5wZGY=
https://www.researchgate.net/profile/Arvind_Singh56/post/I_would_like_to_know_what_is_ the_ecological_restoration_of_a_fo rest_and_why_is_ it_so_important/attachment/59d641aa79197b807799d9af/AS%3A435934916288512%401480946391722/download/1.pdf

XII. Suggested Websites

https://nieindia.org
http://www.uky.edu/hort/Propagation-Seed-Ecology
https://ecology.uni-hohenheim.de
https://www.biologie.uni-regensburg.de/seed ecology
https://researchonline.jcu.edu.au/52954/
http://agris.fao.org/agris-search/search.do?recordID=US201600101233
https://www.oxfordbibliographies.com/view/document/obo-9780199830060/obo-978019983 0060-0086.xml

I. Course Title : Seed Planning, Trade and Marketing
II. Course Code : SST 610
III. Credit Hours : 2 (1+1)

IV. Why this course?

Introduction of high yielding varieties and hybrids in various crops enhanced the International trade on seeds. To meet the international and domestic seed demand, well-structured planning and marketing is essential. This course will expose the students to gain knowledge and skill on planning for a sound seed programme and procedures of trade and to address the trade related issues.

V. Aim of the course

To impart knowledge on planning seed production programmes, national and international movement of seeds and marketing strategies.

VI. Theory

Unit I

Seed industry – genesis, history and growth – structure of seed industry in India – mission and objectives of seed Industry; status and role of seed industry in Indian agriculture.

Unit II

Seed production programmes – characters, types; planning and organizing seed programmes in public and private sectors – small, medium, large and more advanced seed programmes – local, national and international seed programmes; seed demand forecasting – purpose – methods and techniques – factors determining seed demand – seed multiplication ratio, seed replacement rate and variety replacement rate; seed production planning for varieties and hybrids – compact area approach and seed village – contractual seed production – custom seed production – public private partnership – transgenic seeds – demand assessment.

Unit III

New seed policy – genesis – functions; WTO – Indian seed industry – patenting and *suigeneris* system – The Seeds Bill, 2004 and 2011; role and contributions of MNC's in seed trade in India; International trade of seeds – government policies – International organizations involved in seed movement and trade – International Seed Federation (ISF), ISTA – OECD seed schemes – operational guidelines; import and export of seeds – Exim policies – guidelines and salient features; seed production and quality control systems in SAARC Nations and other developed countries; quarantine measures – procedures, guidelines and certificates in international seed movement and trade.

Unit IV

Seed production and distribution system in central and state governments, co-operative and private organisations – seed marketing – definition, concept, importance and type of markets – domestic and global market – problems and perspectives; marketing polices – seed marketing schemes, marketing channels – responsibilities of dealers – marketing mix; handling and management of sales return seed stocks.

Unit V

Seed pricing – local market rate – factors affecting prices and pricing policies – fixation of procurement and sale price of seeds – cost analysis – seed market intelligence – marketing promotional activities; seed supply chain management – missing link – risk and management.

VII. Practical

- Data collection on status of Indian and global seed industry;
- Planning seed programmes for varieties and hybrids;
- Planning for establishment of small and medium seed enterprises;
- Planning for establishment of large scale seed enterprises;
- Planning for custom seed production and contractual seed production;
- Assessment of seed demand – demand forecasting methods;
- Assessment of seed multiplication ratio, seed replacement rate and variety replacement rates for different crops;
- Study on the economics of seed production and marketing;
- Exercise on fixing procurement and sale price of seeds;
- Study of seed marketing channels – survey and interaction with seed dealers and distributors;
- Visit to plant quarantine station and study of quarantine requirements and certificates for domestic and international seed trade;
- Visit to modern seed processing unit, advanced seed storage complex and interactions;
- Visits to state seed corporations;
- Visit to MNCs and expert discussion;

- Case studies and SWOT analysis;
- Planning for establishment of new seed ventures and project preparations;

VIII. Teaching methods

- Classroom lectures
- Students assignment and presentations
- Group discussions
- Field visits and industry visits

IX. Learning outcome

Completion of this course will enable the students to gain knowledge and to start successful seed business.

X. Suggested Reading

Acharya SS and Agarwal NL. 2004. *Agricultural Marketing in India*, 4th Ed. Oxford and IBH.
Agrawal RL. 1996. *Seed Technology*. Oxford, IBH Publishing Co., New Delhi, India.
Broadway AC and Broadway A. 2003. *A Text Book of Agri-business Management*.
Dadheech PK. 1996. *Seed Programming, Management System and Concepts*. Lok Sahitna Kendra, Jodhpur.
Feistrizer P and Fenwickkelly A. 1978. *Improved Seed Production*. FAO, Rome, Italy.
Gurudev Singh and Asokan SR. 1997. *Management of Seed Production Activity*. Oxford and IBH Publishing Co., New Delhi, India.
Joshi AK and Singh BD. 2004. *Seed Science and Technology*. Kalyani Publishers, New Delhi, India.
Kalyani Singh AK and Pandey S. 2005. *Rural Marketing*. New Age Publications.
Krishnasamy V, Ponnuswamy AS, Balamurugan P, Srimathi P, Natarajan N and Raveendran TS. 2004. *Compendium on Seed Science and Technology*. Directorate of Publications, Tamil Nadu Agricultural University, Coimbatore, India.
Kugbei S. 2008. *Seed Economics*. Scientific Publishers, Jodhpur.
Singh G and Asokan SR. 1992. *Seed Replacement Rate: Some Methodological Issues*. Indian Institute of Management, Ahmedabad, India.
Singh S. 2004. *Rural Marketing – Focus on agricultural Inputs*. Vikas Publishing House.

XI. Suggested e-books

http://www.pondiuni.edu.in/storage/dde/downloads/mbaii_mm.pdf
http://agricoop.nic.in/divisiontype/seeds
https://www.audiencebloom.com/all-in-one-guide-to-planning-and-lauching-content- marketing-strategy/
https://link.springer.com/chapter/10.1007/978-1-4615-1783-2-15
http://www.fao.org/3/V4450E/V4450E00.htm
https://books.google.co.in/books?id=vPVlBos4WkYC
http://download.nos.org/srsec319new/319EL19.pdf
https://isengewant.de/Marketing-of-Seeds-By-Premjit-Sharma.pdf
https://www.kopykitab.com/A-Handbook-of-Seed-Processing-and-Marketing-by- Gaur-SC

XII. Suggested websites

www.gov.mb.ca
www.agricoop.nic.in
www.agri.nic.in
https://sathguru.com/seed/
http://www.fao.org/3/V4450E/V4450E03.htm
https://www.seednet.gov.in/smis/SMIS-User%20Manual.pdf
https://www.icrisat.org/seed-systems-models-lessons-learned/
https://www.bookdepository.com/Seed-Industry-India-Gurdev-Singh/

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Sciences
– Plant Genetic Resources

Preamble

(Plant Genetic Resources)

Plant Genetic Resources (PGR) constitute the basic raw material required essentially for the crop improvement programmes. Agro-biodiversity is the key to success of any programme. The Indian sub-continent is a centre of diversity for several of our crop plants assuming significance globally. Over the last four decades, national and international communities have repeatedly emphasized the use of PGRs for Food and Agriculture (PGRFA). PGR management encompasses assembling and conserving PGRFA, adding value to them through characterization and evaluation, quarantine, supply of pest-free samples, biosecurity. In a latest study by CGIAR genebanks, the scenario has changed due to "highly politicized nature of access and benefit sharing issues at the international, national and local levels". At ICAR level emphasis has been laid on enhanced utilization of Crop Wild Relatives, effective characterisation and documentation, conservation in genebanks, streamlining of germplasm exchange within the purview of national interest, resolution of controversial issues and implementation of multi-lateral system to develop a good vision for agrobiodiversity management.

In view of the current scenario, need for specialised human resource for teaching cutting edge technology with application of basic as well as applied aspects like germplasm assemblage, handling, access to users with benefits, long term genebanking of international standards, biotechnology, pre-breeding for utilizing wild species for future crop improvement, increasing entrepreneurship, etc., would warrant students to have strong knowledge of practical and management skills which will help them to face the competitiveness in public and private sector.

Hence, restructuring of course curricula and delivery system to match with the present situation was felt. In this proposed revision of curriculum in Plant Genetic Resources, the BSMA sub-group organized a series of meetings and electronic media-led consultations to develop a set of courses suitable for M.Sc. and Ph.D. students of the discipline.

Emphasis was laid on basic concepts of Germplasm Exploration and Plant Systematics, Plant Diversity and Conservation, Genetic Enhancement for PGR Utilization, Genomics in PGR management, as well as the innovative developments for M.Sc. and Phenomics and Genomics for PGR Utilization, Plant Taxonomy, Ecogeography and Ecology for Ph.D. courses. The latest state of the art technologies including biotechnology and molecular biology will enable a complete coverage of the subjects. The basic courses have therefore been kept as compulsory courses which need to be taken by all the students irrespective of the subject specialization or stream from which they entered into PG education. The genomic revolution has generated detailed population genetic data. Big data samples of complete genome sequences of many individuals from natural populations of many species have transformed population genetics inferences on samples of loci to population genomics. Molecular analyses of these is essentially to be taught to students. Hence basic concepts of genetics to develop analytical, quantitative and problem-solving skills in classical and molecular genetics for PGR management is incorporated. One of the courses would be to provide knowledge in genomic tools and their application in PGR exploration, collection, conservation and utilization. To provide knowledge in genomic tools and their application in plant genetic resource exploration, collection, conservation and utilization, one course on plant genomics have been framed to develop high-throughput genome-wide-scale technologies, tools and methodologies to elucidate the basics of genetic traits/ genetic diversity in organisms.

In the era of Intellectual Property Rights (IPRs) it is imperative to teach concepts and instruments of, plant breeder's rights, farmer's rights, access and benefit sharing, international treaties and national legislation related to plant genetic resources which would be done through one course. In addition to conventional hybridization, there is a need for precise tools to decipher the molecular basis of genetic diversity through mapping and sequencing. In one of the courses students would be taught basics of genome structure and organization, generation of molecular markers-basic principles, molecular marker techniques, data handling and analysis of GM. Another course would deal with germplasm data base management using modern tools and softwares. To educate about protecting the economy, environment and plant health from pests and disease including preventing new pests and diseases from arriving, and helping to control outbreaks when they do occur, biosecurity issues for India would be taught.

By intensive discussion with the core faculty, PGR experts and based on the feedback from faculty of ICAR-National Bureau of Plant Genetic Resources, the entire syllabus was restructured with the improvement in existing courses as well addition of new courses. The syllabus was suitably finalized with the view to equip the students to aspire knowledge and skill sets and mould towards entrepreneurship and build themselves to prepare for global competiveness. The BSMA Committee held discussions over four sessions on the topical issues concerning Plant Genetic Resources. The curricula and syllabi were discussed at length in the meetings and workshops. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the committee. The new look and restructured PG programmes in PGR have been designed keeping in view latest international commitments, role of private sector, modern research tools and their applications, supplementary skills required, and to enhance the global competitiveness and employability of our students. Considerable efforts have, therefore gone in for the preparation of this document.

Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses that have been incorporated based on their importance and applied aspects both at national and international level are Genetic Enhancement for PGR Utilization; Genomics in PGR management; Phenomics and Genomics for PGR Utilization; Concepts in Conservation Genetics; Genomic tools and current applications.

Course Title with Credit Load
M.Sc. (Ag.) in Plant Genetic Resources (PGR)

Course Code	Course Title	Credit Hours
PGR 501*	Germplasm Exploration and Plant Systematics	3(2+1)
PGR 502*	Plant Diversity and Conservation	3(2+1)
PGR 503*	Germplasm Characterization and Evaluation	2(1+1)
PGR 504	Genetic Enhancement for PGR Utilization	2(1+1)
PGR 505*	Economic Botany	3(2+1)
PGR 506	Information Management in PGR	2(1+1)
PGR 507*	PGR Exchange and Quarantine	3(2+1)
PGR 508	Genomics in PGR management	2(1+1)
PGR 509	Plant Biosecurity	1(1+0)
PGR 510	Principles of Genetics for PGR Management	2(2+0)
PGR 511	Principles of Plant Breeding for PGR Management	2(1+1)
PGR 512	Concepts in Conservation Genetics	2(1+1)
	Major courses (minimum 20 credits from above courses including *marked Courses)	20
	Minor courses	08
	Supporting courses	06
	Common compulsory courses	05
PGR 591	Seminar	01
PGR 599	Thesis/ Research	30
	Total Credits	**70**

*Compulsory Major Courses

Course Contents
M.Sc. (Ag.) in Plant Genetic Resources (PGR)

I. Course Title : Germplasm Exploration and Plant Systematics*
II. Course Code : PGR 501
III. Credit Hours : 3 (2+1)

IV. Why this course ?

Students need to be educated about the relationships between plants and their evolution, and actual handling of plant specimens during explorations and collections of various germplasm.

V. Aim of the course

The course is designed to make students understand reconstruction of the evolutionary history and classification of plants into taxonomic groups, introduce the students to the theory and practice behind systematic conduct of exploration, ecogeographic survey, sampling strategies, post harvest methods.

VI. Theory

Unit I

History of germplasm exploration, distribution and extent of prevalent genetic diversity; phyto-geographical regions/ ecological zones and associated diversity; Geo-Spatial analysis using GIS (Geographical Information System) tools for mapping eco-geographic distribution of diversity, threatened habitats, remote sensing, use of drones, need for collection missions, Planning and execution, Use of floras, Concept of population and gene pool; gene pool sampling in self- and cross-pollinated and vegetatively propagated species, non-selective, random and selective sampling strategies, coarse and fine grid surveys, planning collection and analyses of eco-geographic data, assessing the threats of genetic erosion.

Unit II

Ethnobotanical aspects of PGR, crop botany, farming systems, collecting wild relatives of crop plants; Post-exploration handling of germplasm collections, preservation of specimens, importance and use of herbaria and preparation of herbarium specimens.

Unit III

Crop Systematics, nomenclature; International code for binomial nomenclature, systems of classification; concept of species and taxa, biosystematics and terminologies for plant description, Classical and modern species concepts, differentiation and evolution of species: speciation, variation within species, phenotypic plasticity.

Unit IV

Taxonomy of higher/ cultivated plants: use of taxonomic literature such as floras, manuals, monographs, indices, catalogues and dictionaries, concept and methods of herbarium and field study, criteria used for classification, identification of plants of economically important families, floristic and monographic works, Modern trends in plant taxonomy – Chemotaxonomy, Numerical taxonomy and Cytotaxonomy; Cronquist system – Angiosperm Phylogeny (AGP) Group classification; molecular systematics – Primary and Secondary metabolites – Semantides; global taxonomic initiatives- barcoding, taxonomic databases.

VII. Practical

- Plant exploration and germplasm collecting, documenting passport data, use of flora and maps, collecting vegetatively propagated species;
- Local field visit for recording of ethnobotanical information/ notes, herbarium collection, report writing on germplasm collecting missions;
- Post exploration handling;
- Collecting wild relatives of crop plants';
- Preparation, maintenance and use of herbarium, Ecogeographical surveys and inventory, Use of GIS in biodiversity mapping and collecting;
- Estimation of genetic diversity in traditional agroecosystems on farm, matrix ranking of farmer selection criteria;
- Classical and modern species concepts and biosystematics, Morphology and anatomy;
- Comparative studies on phytochemistry, Chemotaxonomy;
- Floristic and monographic work; Practical methods for elucidating and proving hypotheses relating to plant speciation, Numerical taxonomy-practice and procedures, Infraspecific categories in relation to population biology, Taxonomic databases and documentation methods in relation to PGR, Taxonomy of crop plants, cultivated species, domesticated species, wild-cultivated continuum, problems and their resolution, newer methods of analysis and interpretation;
- Visit to Biosphere reserves/ renovated degraded ecosystems and Farmer's fields for landraces, visit to NBAGR/ NBPGR Regional stations.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

The student will learn to recognize plant families that is commonly cultivated and also learn to identify crop plants and their wild relatives. Exposure to learn the major principles and methods of plant taxonomy (systematics) will help to instill an appreciation of the application of plant taxonomy in the field of plant breeding science and utilise them in everyday life.

X. Suggested Reading

Barrough PA. 1986. *Principles of Geographic Information System for Land Resources Assessment*. Oxford University Press, Oxford, UK.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The Use of Plant Genetic Resources*. Cambridge University Press.

Brown AHD, Clegg MT, Kahler AL and Weir BS. (eds.) 1990. *Plant population genetics, breeding, and genetic resources*. Sinauer Associates, USA.

Chapman and Hall. 1992. *Global biodiversity: Status of the Earth's living resources*. World Conservation Monitoring Centre, London. xx + 594 pp.

Curran PJ 1985. *Principles of Remote Sensing*. Longman Inc., New York.

Davis PH and Heywood VH. 1963. *Principles of Angiosperm Taxonomy*. Oliver & Boyd, UK. 556 p.
Greuter W, Barrie FR, Burdet HM, Chaloner WG, Demoulin V, Hawksworth DL, Jorgenson PM, Nicolson DH, Silva PC, Trehane P and Mcneill J. 1994. *International Code of Botanical Nomenclature*. Regnum Veg. 131, Koeltz. Sci. Books, Konigstein, Germany. 389 p.
Frankel OH and Michaele ES. 1987. *Conservation and evolution*, Cambridge University Press.
Halewood M, Noriega I and Louafi S. 2013. *Crop Genetic Resources as a Global commons: Challenges in International Law and Governance*.
Harlan, J.R. 1992. Crops and Man (Second Edition), American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA.
Jackson M, Ford-Lloyd B and Parry M. (editors) 2014. *Plant Genetic Resources and Climate Change*.
Jain SK and Rao RR. 1976. *A Handbook of Field and Herbarium Methods*. Today & Tomorrow's Printers & Publishers, New Delhi, India. 157 p.
Lawrence GHM. 1951. *Taxonomy of Vascular Plants*, Indian ed., 1964. Oxford and IBM Publishing Co., Calcutta, India. 323 p.
Maheshwari JK. 1963. *The Flora of Delhi*. Publications and Information Directorate, CSIR, New Delhi. 447 p.
Meerabi G and Pullaiah T. 2015. *Plant Biodiversity Conservation and Management*. Daya Publishing House, Delhi
Porter CL. 1959. *Taxonomy of Flowering Plants*. W.H. Freeman and Co. Inc., USA. 452 p.
Redden R, Yadav SS, Maxted N, Dullo ME, Guarino L and Smith P. 2015. *Crop Wild Relatives and Climate Change*. Willey-Blackwell.
Zeven AC and De wet JMJ. 1982. *Dictionary of Cultivated Plant and their Regions of Diversity*. Pudoc, Wageningen: Centre for Agricultural Publishing and Documentation.

I. Course Title : Plant Diversity and Conservation*
II. Course Code : PGR 502
III. Credit Hours : 3 (2+1)

IV. Why this course ?

Students need to gain knowledge on biodiversity, especially agrobiodiversity and crop wild relatives germplasm conservation with particular emphasis on genebanks for various species and explants.

V. Aim of the course

The students will grasp the science underpinning biodiversity and agro-biodiversity, concept of PGR, threats to diversity and impact of biotic homogenization for the diversity crisis, concerned legal issues and data recording, various concepts and approaches of plant conservation.

VI. Theory

Unit I

Biodiversity an overview: genetic, species and ecosystem diversity, higher plant diversity, species richness and endemism, biospheres, Gene centres, importance of Indian gene centre. Origin and history of agriculture, conservation and agricultural development, the central role of agro-biodiversity: trends and challenges, centers of crop plant origin and diversity, dynamics of domestication, plant domestication and evolution of crop plants, Crop Wild Relatives, patterns of variation, classification of cultivated plants, concept of gene pool, geographical distribution of crops of Indian origin.

Unit II

Status and trends of agrobiodiversity; Global challenges and conservation of agro-biodiversity-*in-situ, ex-situ,*Impact of climate change on agrobiodiversity, Managing plant genetic resources: Basic science issues; Institutional aspects of managing agrobiodiversity, PGR networks.

Unit III

Agrobiodiversity and livelihoods: Food and nutrition systems, Traditional knowledge, TKDL, Farmers' seed systems and participatory breeding, Valuing PGR and ecosystem services; Value chains of neglected and underutilized (potential crop) species, community biodiversity management.

Unit IV

IPR for innovative entrepreneurship International framework and PGR networks; International treaties and policies in relation to agro-biodiversity conservation, sustainable use and germplasm exchange, CBD, UPOV, ITPGRFA, Nagoya protocol, National policies and legal frame work, Biodiversity Act, PPV and FR Act, Global Plan of action, germplasm registration, IP issues with respect to ITKs and communities, safe guarding biodiversity, case studies, digital sequence information *vs* tangible genetic resources, recent advances in biotechnology and synthetic biology, new forms of life and threats to biodiversity.

Unit V

In situ and *ex situ* conservation: concept of biosphere reserves, gene sanctuaries, on-farm conservation, seed genebanks, Perma-frost conservation, field genebanks, botanical gardens, herbal gardens, *in vitro* repositories and cryo-genebanks; short-, medium- and long-term conservation, concept of base, active and working collections. Importance of seed gene banks; seed structure and function; seed storage behavior, physiological and genetic changes during storage, theories of ageing, viability equations, dormancy. Genebank standards for various crops, ISTA, AOSA, Bioversity International guidelines; monitoring viability of stored samples; strategies for revival and rescue of rare genetic material. Multiplication and regeneration of stored germplasm, Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces.

Unit VI

History and principles of plant tissue culture, Laboratory requirement and general techniques, Tissue culture media, Cellular totipotency, Clonal propagation and clonal multiplication, Somatic embryogenesis, Somaclonal variation, Meristem culture and virus elimination, Cell culture, Anther and pollen culture, Genetic engineering, *In vitro* collecting of plant germplasm, *in vitro* techniques in germplasm exchange, *In vitro* conservation strategies, Concept of *in vitro* active, base genebank and DNA genebank, Introduction to plant cryopreservation, Cryopreservation techniques, Cryopreservation of vegetative propagules and *in vitro* explants, Genetic stability.

Unit VII

Complementary strategies for conservation, scientific basis of *In situ on-farm* conservation; social and cultural context, economic analysis in on-farm conservation, factors influencing farmer variety choice, the value of local crop diversity to markets and to farmers, Community seed genebanks, Institutional frameworks for the implementation of on-farm conservation.

VII. Practical

- Legal issues and FAO code of conduct;
- Seed structure and morphology;
- Seed germination and seedling evaluation;
- Seed viability test, seed sampling and purity analysis, seed dormancy and dormancy breaking treatments, moisture testing methods;
- Vigour testing methods and seed leachate analysis, accelerated aging of seeds and their assessment, seed processing and storage in Gene Bank;
- Preparation of stock solutions, media preparation, preparation of explants and culture initiation in monocots and dicots;
- Meristem isolation and culture establishment, subculture of shoots in monocots and dicots, hardening and field establishment of plantlets;
- Preparation of cryoprotectant solutions and regrowth media, isolation of *in vitro* explants and pre-treatment, cryopreservation of *in vitro* cultures- vitrification based techniques, Encapsulation-dehydration technique, etc.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

The students would grasp the science underpinning biodiversity, agricultural biodiversity and conservation imperatives on the global stage. Knowledge on International and National policies and sustainable use of agrobiodiversity would be imbibed by the students.

X. Suggested Reading

Barbara MR, Chin HF and Normah MN. 2013. *Conservation of Tropical Plant Species*, Springer.Frankel OH and Hawks JG. 1975. *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press.

Bewley JD and Black M. 1994. *Seeds: Physiology of Development and Germination*. Second Edition. Plenum Press, New York and London. pp. 445.

Benson EE. (ed.). 1999. *Plant Conservation Biotechnology*. Taylor and Fancis Ltd. London.

Bhojwani, Bhojwani SS and Razdan MK. 1983. *Plant Tissue Culture: Theory and Practice.* Elsevier Science Publishing Co.Inc. New York.

Bhojwani SS and Razdan MK. 1983. *Plant Tissue Culture: Theory and Practice*. Elsevier Science Publishing Co.Inc. New York.

Bhojwani SS and Dantu PK. 2013. *Plant Tissue Culture: An introductory text*. Springer.

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Engels JMM. 1995. In situ *conservation and sustainable use of plant genetic resources for food and agriculture in developing countries*. IPGRI/ DSE.

Engelmann F and Takagi H. (eds). 2000. *Cryopreservation of Tropical Plant Germplasm – Current Research Progress and Application*, IPGRI, Rome/ JIRCAS/Japan.

Ellis RH, Hong TD and Roberts EH. 1985a. *Handbook of Seed Technology for Genebank*. Volume II. Principles and Methodology. International Board for Plant Genetic Resources, Rome.

Ellis RH, Hong TD and Roberts EH. 1985b. *Handbook of Seed Technology for Genebank. Compendium of Specific Germination Information and Test Recommendations*. International Board for Plant Genetic Resources, Rome.

Ford-Lloyd BV, Newburry JH and Callow JA. (eds.) 1998. *Biotechnology and Plant Genetic Resources: Conservation and Use*. CABI, Wellingford.

Guriano L, Ramanatha Rao V and Reid R. 1995. *Collecting plant genetic diversity-Technical Guidelines*. CAB International, Wallingford, UK.

Hong TD and Ellis RH. 1996. A protocol to determine seed storage behaviour. International Plant Genetic Resources Institute IPGRI Technical Bulletin No. 1, Rome.

Jarvis D, Staphit B and Sears L. 2000. *Conserving agricultural biodiversity* in situ: *a scientific basis for sustainable agriculture*. IPGRI, Rome, Italy.

Kartha KK. (ed.). 1995. *Cryopreservation of Plant Cells and Organs*. CRC Press, Boca Rataon, Florida.

Maxted N, Ford-Lloyd BV and Hawkes JG. 1997. *Plant Genetic Conservation: The* In situ *Approach*. Chapman & Hall, London.

McNeely JA. 1988. *Economic and biological diversity: developing and using economic incentives to conserve biological resources*. International Union for Conservation of Nature and Natural Resources, Gland.

Plucknett DL, Smith NJH and Williams JT. 1987. *Genebanks and the World's Food*. Princeton University Press.

Razdan MK and Cocking EC. (eds.) 2000. *Conservation of Plant Genetic Resources* In vitro, Vol. 2: Applications and Limitations. Science Publishers, Inc. USA.

Redden R, Yadav SS, Maxted N, Dulloo ME, Guarino L and Smith P. (eds.) 2015. *Crop wild relatives and climate change*. Wiley-Blackwell. 400 p. ISBN: 978-1-118-85433-4.

e-resource

www.iucnredlist.org

I. Course Title : Germplasm Characterization and Evaluation*

II. Course Code : PGR 503

III. Credit Hours : 2(1+1)

IV. Why this course ?

Students need to learn about morphological and quality agronomic traits of accessions as well as their reaction to biotic and abiotic stresses. This will increase the importance of the germplasm.

V. Aim of the course

Students will gain knowledge on germplasm characterisation, evaluation and documentation of information. Recording of morphological and agronomic traits, including quality, as well as those for resilience to biotic and abiotic stresses that will promote utilisation. Exposure to development of web based tools for systematic description for efficient use of germplasm.

VI. Theory

Unit I

Understanding genetic diversity in crop plants; Crop descriptors, descriptor states; germplasm characterization/ evaluation procedures; evaluation of germplasm for specific traits; Measuring diversity using agro-morphological data, statistical procedures to measure population genetic variation, markers and their use in PGR, evaluation of biotic and abiotic stresses, Principles and methods for formulating core and mini core collections and their validation, Web based tools for management of data.

Unit II

Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces, evaluation and maintenance of wild relatives of crop plants. Genetic enhancement, Use of CWRs genetic resources for crop improvement.

Unit III

High throughput phenotyping systems- imaging and image processing concepts for automated germplasm characterization (phenotyping) – evaluation for nutritional traits, resistance traits -Biochemical and molecular markers for characterization.

VII. Practical

- Field layout and experimental designs;
- Recording field data on germplasm evaluation in different agri-horticultural crops;
- Post harvest handling;
- Evaluating quality traits, biochemical and phyto-chemical evaluation of crop germplasm, data processing;
- Documentation, analysis of diversity and cataloguing, data analysis, viability equations, sampling strategies, data documentation, cataloguing, biochemical analyses of samples.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

To educate students about science of managing genetic resources including principles involved in maintaining genetic integrity during regeneration, germplasm characterization and evaluation.

X. Suggested Reading

Brown AHD, Clegg MT, Kahler AL and Weir BS. (eds.). 1990. Plant Population Genetics, Breeding, and Genetic Resources, Sinauer Associates, USA.

Frankel R and Galun E 1977. 'Pollination Mechanisms, Reproduction and Plant Breeding', *Monographs on Theoretical and Applied Genetics*. Springer-Verlag, Berlin, Heidelberg.

Hayward, MD, Bosemak, NO and Romagosa, I. 1993. Plant Breeding: Principles and Practices, Chapman & Hall.

Holden JHN and Williams JT. 1984. *Crop genetic resources: conservation and evaluation*. IBPGR.

Puzone L and Th. Hazekamp. 1996. *Characterization and Documentation of Genetic Resources* Utilizing Multimedia Database. NBPGR, New Delhi.

Rana RS, Sapra RL Agrawal RC and Gambhir R. 1991. *Plant Genetic Resources, Documentation and Information Management*. NBPGR, New Delhi.

Stoskopf NC. 1993. *Plant Breeding: Theory and Practice*. Westview Press.

Sundeep Kumar, *et al.* 2016. *Evaluation of 19,460 wheat accessions conserved in the Indian national genebank to identify new sources of resistance to rust and spot blotch diseases*. PloS One Vol 11, pages 0167702.

Tripathi K, Bhardwaj R, Bhalla S, Kaur V, Bansal R, Yadav R, Gangopadhyay KK, Kumar A and Chaudhury R. 2018. *Plant Genetic Resources Evaluation: Principles and Procedures*.

Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi. vi+50 p.

I. Course Title : Genetic enhancement for PGR Utilization

II. Course Code : PGR 504

III. Credit Hours : 2(1+1)

IV. Why this course ?

Pre-breeding is a vital step in the link between plant genetic resources conservation and its use; Hence, this course is designed to inculcate theoretical and practical know how to understand and use classical and advanced plant breeding methods for planning and execution of prebreeding programmes so that the PGR is put into effective use for food and agriculture.

V. Aim of the course

To teach theoretical and practical know how on CWRs reproductive behavior, acclimatization and adaptation for utilization in prebreeding programmes usig advanced tools.

VI. Theory

Unit I

Concepts of gene pools; Introduction, potential of pre-breeding. Role of crop wild relatives, semi exotics, creating and managing variation, basic concepts to set up a successful pre-breeding programme.

Unit II

Understanding crop adaptation, handling and maintenance of CWRs, synchronization of flowering, overcoming impediments to flowering through photoperiodic adjustments, role of other barriers to flowering, role of amphidiploids, semi exotics and other unadapted germplasm, identifying desirable traits in natural populations, screening for biotic and abiotic stress resistance traits; screening of nutritionally important traits, genetic analysis to understand the inheritance of novel traits.

Unit III

Parental selection for prebreeding, search for superior genotypes, breeding methods for trait transfer; moving the genes – unadapted to adapted, wide hybridization, Incongruity and its management, modern tools for incongruity management, cytogenetical approaches for gene transfer such as alien addition and substitution, segregating populations and their management in wide crosses, purging the undesirable traits, testing and improving the adaptability of wide cross derivatives, cytological studies, florescence microscopy, embryo rescue methods, pollen physiology and storage, pollen storage methods to facilitate wide hybridization, pre- and post-zygotic barriers.

VII. Practical

- Characterization of CWRs by visiting the fields;
- Screening methods for special traits-biotic and abiotic resistance;
- Screening for nutritional traits;
- Crossability studies in CWRs of cereals, legumes, oilseeds, vegetables. Assessment of pre and post-zygotic barriers in wide hybridization crosses;
- Pollen storage studies;

- Special requirements for growing CWRs, inducing flowering by manipulating day length, temperature, chemical spraying, etc.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students would be conversant with handling of unadapted germplasm, screening methods for special traits-biotic and abiotic resistance, nutritional traits, characterization of CWR, breeding, etc.

X. Suggested Reading

Andey Pereira. 2006. *Plant Reverse Genetics: Methods and Protocols*. Humana Press

Bisht *et al*. 2004. 'Broadening the genetic base of sesame (*Sesamum indicum* L.) through genetic enhancement.' *Plant Genetic Resources* **2**(3): 143-151.

Duvick DN. 1990. 'Genetic enhancement and plant breeding', p. 90-96. In: J Janick and JE Simon (eds.), *Advances in new crops*. Timber Press, Portland.

Dale, JW and von Schantz, M. 2007. From genes to genomes. Concepts and applications of DNA technology. John Wiley & Sons Ltd., Chichester, England.

Goodman, RM. 2004. Encyclopedia of plant and crop science. Marcel Dekker Inc., Switzerland.

Kimber, G and Feldman, M. 1987. Wild Wheat: An introduction. Special report 353, College of Agriculture, University of Missouri-Columbia.

Lynch, M. and Walsh, B. 1998. Genetics and analysis of quantitative traits. Sinauer Associates Inc., MA, USA.

Murphy, D. 2007. Plant breeding and biotechnology: Societal context and the future of agriculture. Cambridge University Press, Cambridge, UK.

Ram JS. 2010. Plant Cytogenetics. CRC Press.

Ramanatha Rao V, Brown AHD, Jackson M. 2001. *Managing Plant Genetic Diversity*. CABI Publication.

Sharma S, Upadhyaya HD, Varshney RK, *et al*. 2013. 'Pre-breeding for diversification of primary gene pool and genetic enhancement of grain legumes.' *Frontiers in Plant Science* **4**: 309.

Yunbi Xu. 2010. Molecular plant breeding, CABI publishers

e-Resources

https://www.integratedbreedPlaning.net/pre-breeding-effective-use-plant-genetic-resources http://www.croptrust.org/ http://www.bioversityinternational. org/training/training_materials/pre_breeding.htm http://www.grdc.com.au/director/research/prebreeding

I. Course Title : Economic Botany *

II. Course Code : PGR 505

III. Credit Hours : 3(2+1)

IV. Why this course ?

To study the relationship between people and plants including anthropology, botany and use.

V. Aim of the course

The student will learn concept of economic botany and relationship between human and plants including cultivation and economic uses in everyday life.

VI. Theory

Unit I

Introduction to economic botany, Origin of agriculture, domestication and adaptations of cultivated plants, classification into crop groups, reproductive systems and breeding behaviour of crop plants.

Unit II

Origin, evolution, botany, cultivation, use, genetic resource management and utilization of important crops, viz., cereals, pseudo-cereals, millets, legumes, forage and fodder crops, oil yielding plants, fibre yielding plants, under-utilized and under-exploited plants, new and potential crops, processing and use of crop residues.

Unit III

Important taxa in horticulture, floriculture and agro-forestry. Origin, evolution, botany, cultivation, use, genetic resource management and utilization of genetic diversity of important crops, viz., vegetable crops, fruits and nuts, medicinal and aromatic plants, spices and condiments, beverages, fumitory and masticatory plants, rubber yielding plants, wood and timber yielding taxa, cellulose, starch and sugar yielding plants, insecticidal and herbicidal plants, important taxa in agro-forestry, flavouring agents, gums and resins.

VII. Practical

- Botanical microtechniques for the study of structure, development and biochemical status of plant parts;
- Identification of economically important plant parts in different groups of plants-oil yielding plants, cereals, millets, legumes, spices, condiments, woods, timber and industrial crops, medicinal and aromatic plants and fumitory, masticatory plants;
- Structure of economic plant parts-root, stem, leaves, fruits, seeds, recognizing the grains;
- Case studies on adaptations during domestication;
- Histochemical localization of chemical constituents in economically important plant parts e.g. starch-sugars, Proteins-lipids; and studies on sugar, starch, cellulose, fibers, gums, rubber and resins;
- Visit to Museum of economic products in other Institutes, visit to industrial units processing the economic products.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

The student will learn concept of economic botany in the field of plant science and utilise them in everyday life.

X. Suggested Reading

Atkinson ET. 1980. *The Economic Botany of the Himalayas*.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The use of plant genetic resources*. Cambridge University Press.

Burkill IH. 1951-52. Habits of man and the origins of the cultivated plants of the old World. *Proceeding Linnean Society of London*, 164: 12-42.
Frankel OH and Hawks JG. 1975. *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press.
George W. 2014. *Dictionary of Economic Products of India*. Cambridge University Press.
Hanelt P. 2001. *Mansfeld'sencyclopedia of agricultural and horticultural crops*, vol 3. Institute of Plant and Genetics and Crop Plant Research (eds) Springer, Berlin.
Harlan JR. 1992. *Crops and Man* (Second Edition). American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA.
Hill AF. 1952. *Economic Botany: A Textbook of Useful Plants and Plant Products*. Second Edition. New York Toronto London McGraw-hill Book Company, Inc.
Kochhar SL. 2012. *Economic Botany in the Tropics*. Paperback, Fourth edition. Laxmi Publications.
Maiti RK and Singh VP. 2006. *An Introduction to Modern Economic Botany*. Eastern Book Corporation, Delhi.
Mehra KL and Arora RK. 1982. *Plant Genetic Resources of India: their diversity and conservation*. NBPGR, New Delhi.
Morton JF. 1987. *Fruits of warm climates*. Creative Resource Systems. Inc. NC Miami, FL.
Paroda RS and Arora RK (eds.). 1991. *Plant Genetic Resources: Conservation and Management*. NBPGR, New Delhi.
Purseglove W. 1981. *Tropical Crops. Dicotyledons*. The English Language Book Society and Longman.
Purseglove W. 1981. *Tropical Crops. Monocotyledons*. The English Language Book Society and Longman.
Schery RW. 2001. *Plants for Man*.
Simpson BB and Ogorzaly M. 2013. *Plants in Our World: Economic Botany*, McGraw-Hill Education, New York, NY.
Simpson BB, Molly Ogorzaly, Simpson Beryl. 2001. *Economic Botany: Plants in Our World*. Mcgraw-hill Science/ engineering/ math.
Swaminathan MS and Jana S (eds.). 1992. *Biodiversity: implication for global food security*. Mc MIllan Press.
Wealth of India: Raw material series, CSIR, India

I. Course Title : Information Management in PGR

II. Course Code : PGR 506

III. Credit Hours : 2 (1+1)

IV. Why this course ?

Vast amount of information is generated in various disciplines and it needs to be documented in proper way.

V. Aim of the course

To train students in germplasm data base management using modern tools and softwares.

VI. Theory

Unit I

Documentation of germplasm collections, principles of documentation of information in genebanks, concept of data base creation and management; Relational Database Management Systems; Web based PGR networks.

Unit II

Statistical techniques in management of germplasm, developing core collection, estimating sample size during plant explorations, impact of sampling on population structure.

Unit III

Sequential sampling for viability estimation, introduction of binomial, normal and negative cumulative normal, use of Probit scales, viability equations and nomograms, estimation of sample size for storage and viability testing. Germplasm documentation; basics of computer and operating systems, database management system- PGR Portal, Cryodatabase, *In vitro* genebank database, use of statistical softwares, pictorial and graphical representation of data; Introduction to communication network.

Unit IV

Introduction to database management and DBMS, Introduction to Perl and Bioperl. Collection and storage of sequences, NCBI- providing access to biomedical and genomic information.

VII. Practical

- Experimental designs and data analysis;
- Viability equations, sampling strategies, data documentation;
- Cataloguing;
- PGR portal, Cryodatabase management;
- Writing programmes in Perl for bioinformatics applications.

VIII. Teaching methods

- Lectures
- Power point presentations
- Assignments, quiz
- Group tasks, student's presentations
- Hands-on-learning on computer

IX. Learning Outcome

Students would be well versed with database management system and use of statistical softwares.

X. Suggested Reading

Agrawal RC, Archak S and Tyagi RK. 2012. *An overview of biodiversity information with special reference to PGR*. Computer and Electronics in Agriculture 84: 92-99.

Archak S and Agrawal RC. 2013. *PGR informatics at the NBPGR: Status, challenges and future*. In A road map for implementing the MLS of ABS in India (Eds Halewood, M, Brahmi, P.Mathur, PN and Bansal, KC). Bioversity International, Rome and NBPGR, New Delhi.

Painting KA, Perry MC, Denning RA and Ayad WG. 1993. *Guide Book for Genetic Resources Documentation*. IPGRI, Rome, Italy.

Puzone L and Th. Hazekamp. 1996. Characterization and Documentation of Genetic Resources Utilizing Multimedia Database.

Rana RS, Sapra RL, Agrawal RC and Gambhir R. 1991. *Plant Genetic Resources*. Documentation and Information Management, NBPGR, New Delhi.

I. Course Title : PGR Exchange and Quarantine *

II. Course Code : PGR 507

III. Credit Hours : 3(2+1)

IV. Why this course ?

In view of updated rules and regulations for access of germplasm and its safe movement following international phytosanitary measures, these issues need to be taught in detail.

V. Aim of the course

To impart knowledge onsafe exchange of germplasm nationally and internationally alongwith the quarantine related issues which are either legislative or technical.

VI. Theory

Unit I

History, principles, objectives and importance of plant introduction, pre-requisite and conventions for exchange of PGR, national and international legislations and policies.

Unit II

Principles, objectives and relevance of plant quarantine, regulations and plant quarantine set up in India, pest risk analysis, pest and pathogen information database; quarantine in relation to integrated pest management, symptoms of pest damage, economic significance of seed-borne pests (insects, mites, nematodes, fungi, bacteria, viruses, phytoplasma, viroids, weeds, etc.), detection and identification of pests including use of recent techniques like ELISA, PCR, etc.

Unit III

Salvaging techniques for infested/ infected germplasm, post-entry quarantine operation, seed treatment and other prophylactic treatments and facilities, domestic quarantine; seed certification; international linkages in plant quarantine, weaknesses and future thrust. Symptoms of pest damage, pests of quarantine significance for India, sampling of bulk material for quarantine, Plant Quarantine/ biosecurity system in other countries, case histories of alien invasive species.

Unit IV

Genetically Modified Organisms (GMOs) or Genetically Engineered Plants (GEPs), Concepts of biosafety, risk analysis and consequences of spread of GE crops on the environment; Treaties and multilateral agreements governing trans-boundary movement of GEPs or GMOs, Indian regulatory system for biosafety.

VII. Practical

- Inventory of IQ/ EQ samples;
- Joint inspection for pest detection;
- Detection of pests of quarantine significance (Conventional, Electron microscopy, ELISA and molecular techniques);
- Primer designing;
- Pest risk analyses, quarantine in relation to integrated pest management; salvaging of infested/ infected germplasm;
- Seed treatment and other prophylactic treatments and facilities; domestic quarantine; seed-health certification.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student’s presentations
- Hands-on-learning on computer

IX. Learning Outcome

Knowledge gain on current national and international regulations related to germplasm exchange and plant quarantine, detection techniques for pests, salvaging methods, sampling techniques, biosafety of transgenics, etc.

X. Suggested Reading

Albrechsten SE. 2006. *Testing methods for seed-transmitted viruses: principles and protocols*. UK: CAB International, Wallingford. 268 p.

Bhalla S, Chalam VC, Tyagi V, Lal A, Agarwal PC and Bisht IS. 2014. Teaching Manual on Germplasm Exchange and Plant Quarantine. ICAR-NBPGR, New Delhi, India p. 340+ viii.

Bhalla S, Chalam VC, Lal A, and Khetarpal RK. 2009. *Practical Manual on Plant Quarantine*. National Bureau of Plant Genetic Resources, New Delhi, India. 204p+viii.

Bhalla S, Chalam VC, Singh B, Gupta K and Dubey SC. 2018. Biosecuring Plant Genetic Resources in India: Role of Plant Quarantine. ICAR-NBPGR, New Delhi vi+216 p.

Chalam VC, Dubey SC, Murali Krishna C, Bhalla S and Singh K (eds.). 2018. *Transboundary Movement of Living Modified Organisms: Strengthening Capacities of Enforcement Agencies*. ICAR-National Bureau of Plant Genetic Resources and Ministry of Environment, Forest and Climate Change, New Delhi, India. vi+159 p. ISBN 978-81-937111-2-5

Gupta K and Dubey SC. 2017. 'Biosecurity policies influencing international exchange of PGR.' *Indian Journal of Plant Genetics Resources* **30**: 258-266.

Khetarpal RK, Lal A, Varaprasad KS, Agarwal PC, Bhalla S, Chalam VC and Gupta K. 2006. Quarantine for Safe Exchange of Plant Genetic Resources. In: *Hundred Years of Plant Genetic Resources Management in India* (eds. AK Singh, Kalyani Srinivasan, Sanjeev Saxena and BS Dhillon), National Bureau of Plant Genetic Resources, New Delhi, pp 108-139.

Richardson MJ. 1990. An Annotated list of seed-borne diseases (Fourth Edition). International Seed Testing Association, P.O. Box 412. CH 8046 Zurich, Switzerland.

I. Course Title : Genomics in PGR management

II. Course Code : PGR 508

III. Credit Hours : 2 (1+1)

IV. Why this course ?

In addition to conventional hybridization, there is a need for precise tools to decipher the molecular basis of genetic diversity through mapping and sequencing.

V. Aim of the course

Students would be taught basics of genome structure and organization, generation of molecular markers-basic principles, molecular marker techniques, data handling and analysis of GM.

VI. Theory

Unit I

Structure and function of DNA, genome organization, tools and techniques for genetic manipulation, Introduction to genetic markers, classification and comparison of markers, basis for DNA polymorphism and principles of generating molecular markers- RFLP, PCR, sequencing, next generation sequencing techniques, molecular marker techniques eg. RAPD, ISSR, AFLP, etc.; STMS, SNPs markers, GBS, GWAS, data handling and statistical analysis.

Unit II

Overview of molecular marker applications and recent advances, genetic diversity analysis using molecular markers, DNA Fingerprinting and cultivar identification.

Unit III

Introduction to transgenics, development of genetically modified crops, monitoring strategies and methods for detecting transgenics, Genome Editing.

VII. Practical

- DNA isolation and purification, DNA quantification;
- RAPD, ISSR, STMS, SCAR, SRAP;
- Data Analysis.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Knowledge on current state-of-the-art technological developments of genomics era, current challenges being faced and handled.

X. Suggested Reading

BD Singh and Singh AK (Eds). 2015. *Marker-assisted Plant Breeding: Principles and Practices.* Springer.

Henry RJ. (Editor). 2001. *Plant Genotyping: The DNA Fingerprinting of Plants,* CABI Publishing.

Henry R (ed.) 2013. Molecular Markers in Plants. Wiley and Blackwell Publication, Iowa USA, 196 p.

Lewin B. 2008. Genes IX. Jones and Bartlett.

Karp A, Isaac PG and Ingram DS. 1998. *Molecular Tools for Screening Biodiversity– Plants and Animals.* Chapman and Hall, London.

Tuberosa R, Graner A and Frison E (eds.). 2014. Genomics of Plant Genetic Resources, Volume 1. Managing, Sequencing and Mining Genetic Resources. Springer Science, New York, 825 p.

Varshney RK and Tuberosa R (eds.) 2007. Genomics-Assisted Crop Improvement Vol 2: Genomics Applications in Crops. Springer Dordrecht, The Netherlands, 509 p.

I. Course Title : Plant Biosecurity

II. Course Code : PGR 509

III. Credit Hours : 1(1+0)

IV. Why this course ?

Safe transboundary movement of germplasm to biosecureindia against the ravages of exotic pests is important and hence need to understand the basics.

V. Aim of the course

To educate about protecting the economy, environment and plant health from pests and disease including preventing new pests and diseases from arriving, and helping to control outbreaks when they do occur.

VI. Theory

Unit I

History of biosecurity, concept of biosecurity, components of biosecurity, Quarantine, Invasive Alien Species, biowarfare, emerging/ resurgence of insects, pests and diseases.

Unit II

National Regulatory Mechanism and International Agreements/ Conventions, viz., Agreement on Application of Sanitary and Phytosanitary (SPS) Measures/ World Trade Organization (WTO), Convention on Biological Diversity (CBD), International Standards for Phytosanitary Measures, pest risk analysis, risk assessment models, pest information system, early warning and forecasting system, use of Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/ disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity.

Unit III

Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, Issues related to release of genetically modified crops.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Knowledge gain on current national and international regulations related to plant biosecurity

I. Course Title : Principles of Genetics for PGR Management

II. Course Code : PGR 510

III. Credit Hours : 2(2+0)

IV. Why this course ?

Students need to understand all the basic principles of genetics to be able to exploit the PGR

V. Aim of the course

To understand basic concepts of genetics and to develop analytical, quantitative and problem-solving skills in classical and molecular genetics for PGR management.

VI. Theory

Unit I

History and role of genetics in crop improvement, polyploidy, mutation, genetic diversity in PGR, genetic principles of diversity and its distribution, evolution of crop plants through ploidy manipulation.

Unit II

Cytology-euploidy, haploid, diploid, polyploids, chimeras, role of polyploids in crop breeding, evolutionary advantages of autopolyploids vs allopolyploids, Role of aneuploids in basic and applied aspects of crop breeding, apomixis, haploids and their uses, modes of reproduction, male sterility, CMS, heterosis and hybrid development.

Unit III

Methods of studying polymorphism, Overview of molecular marker applications and recent advances, genetics of mitochondria and chloroplast, extra chromosomal inheritance, eugenics, epigenetics, basics of genome structure and organization, generation of molecular markers-RFLP, PCR, sequencing; principles, merits and demerits of RAPD, ISSR, SSR, SCAR, SCOT, SRAP, AFLP, SNP.

Unit IV

Population-Mendelian Population, random mating population, frequencies of genes and genotypes, causes of change, Hardy-Weinberg equilibrium.

VIII. Teaching methods

- Lectures,
- Power point presentations,
- assignments, quiz,
- Group tasks, student's presentations

IX. Learning Outcome

Knowledge and skill gain on current basic and advanced methodologies in genetics

X. Suggested Reading

Griffin HG and Griffin AM. 1994. *PCR Technology: Current Innovations*. CRC Press, London.
Hancock JF. 2004. *Plant Evolution and Origin of crop species*, 2nd edition. CABI.
Henry RJ (Editor). 2001. *Plant Genotyping: The DNA Fingerprinting of Plants*. Publisher: CABI Publishing.
Karp A, Isaac PG and Ingram DS. 1998. *Molecular Tools for Screening Biodiversity – Plants and Animals*. Chapman and Hall, London.
Miller AJ. 2007. *Crop Plants: Evolution*. John Wiley and Sons.

I. Course Title : Principles of Plant Breeding for PGR Management
II. Course Code : PGR 511
III. Credit Hours : 2(1+1)

IV. Why this course ?

Students need to understand all the basic principles of plant breeding to be able to exploit the PGR.

V. Aim of the course

To impart theoretical knowledge and practical skills about plant breeding objectives in PGR management especially for germplasm maintenance, regeneration and pre-breeding.

VI. Theory

Unit I

Objectives of plant breeding, genetic basis of breeding self- and cross – pollinated crops, nature of variability, components of variation, genotype-environment interaction, general and specific combining ability, self-incompatibility and male sterility in crop plants and their commercial exploitation.

Unit II

Principles of breeding for biotic and abiotic stresses, Breeding self pollinated and cross pollinated crops, pure line theory; pure line selection and mass selection methods, line breeding, pedigree, bulk, backcross, single seed descent and multiline method. Breeding methods in asexually/ clonally propagated crops, clonal selection.

Concept of plant ideotype and its role in crop improvement. Participatory Plant Breeding, Plant breeders' rights and regulations for plant variety protection and farmers rights, DUS testing.

Unit III

Molecular breeding-molecular markers, fundamental concepts in the development of molecular markers, types (isozymes, RFLP, RAPD AFLP), mapping populations (RILs, NILs, DH, Backross), their merits and demerits, markers assisted selection, linkage disequilibrium and the concept of marker-trait association-case studies, marker assisted pre-breeding programmes.

VII. Practical

- Floral biology in self and cross pollinated species, selfing and crossing techniques;
- Selection methods in segregating populations and evaluation of breeding material.
- Analysis of variance (ANOVA);
- Estimation of heritability and genetic advance, maintenance of experimental records;
- Learning techniques in hybrid seed production using male-sterility in field crops.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Knowledge gain on plant breeding principles and applications

X. Suggested Reading

Allard RW. 1981. *Principles of Plant Breeding*. John Wiley & Sons.
Chopra VL. 2001. *Breeding Field Crops*. Oxford & IBH.
Chopra VL. 2004. *Plant Breeding*. Oxford & IBH.
Poehlman JM and Borthakur DN. 1972. *Breeding Asian Field Crops*. Oxford & IBH.
Roy D. 2003. *Plant Breeding, Analysis and Exploitation of Variation*. Narosa Publ. House.
Sharma JR. 2001. *Principles and Practice of Plant Breeding*. Tata McGraw-Hill.
Simmonds NW. 1990. *Principles of Crop Improvement*. English Language Book Society.
Singh BD. 2006. *Plant Breeding*. Kalyani Publishers, New Delhi.

I. Course Title : Concepts in Conservation Genetics
II. Course Code : PGR 512
III. Credit Hours : 2(1+1)

IV. Why this course ?

To provide knowledge in genomic tools and their application in plant genetic resource (PGR) exploration, collection, conservation and utilization.

V. Aim of the course

Conservation genetics focuses on processes within small and fragmented populations and on practical approaches to minimize deleterious effects on them. This course will introduce students to the relatively young discipline of conservation genetics with the basic understanding on genetic and epigenetic principles. Emphasis will be placed on general principles rather than specific experimental procedure. A basic knowledge of Mendelian genetics and simple statistics is a prerequisite for registering this course.

VI. Theory

Unit I

Genetic material, cell division, chromosomes, nucleic acids, biological significance of DNA, Mendelian principles I and II, calculation of genetic ratios, Chi-Square method, dominance, Gene Interaction, multiple alleles, sex determination, extranuclear inheritance, quantitative inheritance, linkage and recombination, genetic map, environmental effects – external and internal, phenocopies, concordance, discordance, epigenetics, environmental epigenetics, DNA methylation, histone modification, gene environment vs epigene environment, epigenetic inheritance.

Unit II

Modern Synthesis Theory – Endangered and extinct species – causes of extinctions – Structure and content of conservation genetics – genetics and extinctions – Genetic versus demographic and environmental factors in conservation biology – Limitations of Genetics in Conservation Biology.

Unit III

Hardy Weinberg Principle, proportions – deviations from Hardy–Weinberg equilibrium, Inbreeding – Assortative and dissassortive mating, extensions of Hardy –Weinberg equilibrium, evolutions in large population, natural selection and adaptation, directional, stabilizing and disruptive selection, mutation, migration and their interaction, evolution in small population, genetic drift, inbreeding, inbreeding depression, outbreeding, outbreeding depression, population fragmentation, gene flow.

Unit IV

Genetically viable populations, reproductive fitness, population viability analysis, recovery of endangered species/ threatened population, legal issues related to endangered species and their protection, minimum viable population, recovery of endangered species, legal issues related to endangered species and their protection.

VII. Practical

- Deriving Hardy Weinberg equilibrium, problems on Hardy Weinberg equilibrium, calculation of gene frequencies, autosomal loci with two alleles, estimation of gene frequencies, autosomal loci with multiple alleles, estimation of gene frequencies;
- Sex linked loci, estimation of inbreeding co-efficient – problems in epigenetics, genetic variability of threatened populations, hybridization and introgression analysis;
- Plant forensics, storage of plant genetic samples for time-series analyses.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Complete understanding of conservation genetics for PGR handling

X. Suggested Reading

Allendorf. FW. 2007. *Conservation and the genetics of populations*. Blackwell Publishing Ltd, Australia.

Frankham R, Ballou JD and Briscoe DA. 2004. *A primer of Conservation Genetics*. Cambridge University Press

Frankham R, Ballou JD and Briscoe DA. 2009. *An Introduction to Conservation Genetics*, 2nd edition. 2009. Cambridge University Press: Cambridge, UK.

Höglund J. 2009. *Evolutionary Conservation Genetics*. Oxford University Press, USA.

Strickberger MW. 1996. *Genetics*, Prentice Hall of India Pvt Limited.

Tollefsbol T. 2017. Handbook of Epigenetics, Elsevier.

e-Resources

http://www.scu.edu.au/research/cpcg/

http://genetics.forestry.ubc.ca/cfcg/

Course Title with Credit Load
Ph.D. in Plant Genetic Resources (PGR)

Course Code	Course Title	Credit Hours
PGR 601*	Recent Advances in Germplasm Conservation	2(1+1)
PGR 602*	Phenomics and Genomics for PGR Utilization	2(1+1)
PGR 603*	Economic Botany and Crop Diversification	2(1+1)
PGR 604	PGR Policies and Regulatory Mechanisms	1(1+0)
PGR 605	Molecular Population Genetics in PGR Management	3(2+1)
PGR 606	Plant Taxonomy, Ecogeography and Ecology	2(1+1)
PGR 607	*In-situ on farm* conservation	2(1+1)
PGR 608	Genomic tools and current applications	3(2+1)
PGR 609*	Intellectual Property Rights and Regulatory Mechanisms (e-course)	1(1+0)
	Major courses (Minimum 12 credits from above courses including *marked Courses)	12
	Minor courses	06
	Supporting courses	05
PGR 691	Seminar I	01
PGR 692	Seminar II	01
PGR 699	Thesis/ Research	75
	Total Credit Hours	**100**
	Comprehensive (Pre-qualifying) Examination (Non-credit of 100 marks) Satisfactory/ Not satisfactory	

*Compulsory major courses

Course Contents
Ph.D. in Plant Genetic Resources (PGR)

I. Course Title : Recent Advances in Germplasm Conservation*

II. Course Code : PGR 601

III. Credit Hours : 2(1+1)

IV. Why this course ?

Students need to understand all the recent and current issues and procedures for germplasm conservation

V. Aim of the course

To provide knowledge on advances in seed physiology, biology and banking to lead to retention of high seed quality during conservation and all aspects of conservation science and technology.

VI. Theory

Unit I

Seed development and maturation; Seed storage behavior: physiological and molecular basis of desiccation sensitivity; Dormancy, seed germination- mobilization of reserves and their control processes; Viability and vigour-principle and testing procedures; Seed testing for inadvertent introduction of transgenes.

Unit II

Seed storage for long-term conservation and factors affecting seed longevity; seed processing for short, medium and long-term storage, artificial aging and controlled deterioration test; ultra-desiccation techniques for germplasm conservation, richness index, ecological correlates of *ex-situ* seed longevity, permafrost conservation, maintenance of Seed Genebank, status of global seedgene banks.

Unit III

In-vitro techniques in PGR management, *In-vitro* methods of clonal propagation, *In-vitro* collecting and germplasm exchange, Meristem culture and virus elimination, somaclonal variation, application of somatic embryogenesis in PGR, Methods of *in-vitro* conservation- short, medium-term and long term, Concept of active and base *in-vitro* genebank, Status of World cryo- and cryo-gene banks, embryo rescue technique, history and principles of cryopreservation, cryoprotectants- role and applicability, freezing injury and factors affecting cryoprotection, methods of cryopreservation-conventional and vitrification based techniques, varied applications of cryopreservation, handling difficult-to store non-orthodox seeds, embryonic axes, pollen and dormant buds, Management of *in-vitro*, cryo and DNA genebank- Practical considerations, Monitoring genetic stability of *in-vitro* conserved and cryopreserved germplasm, database management for *in-vitro* and cryopreserved germplasm

VII. Practical

- Seed morphology and structure;

- Desiccation rates and freezing to low and ultra low temperatures, seed storage behavior determination in sample seeds, seed viability and vigour tests;
- Seed longevity and accelerated ageing test in different types of seeds, handling hard seededness and physiological immaturity;
- Post harvest handling methods of difficult-to-store seeds, dormant buds, and pollen, ultra-desiccation of seeds, biochemical tests of seed deterioration;
- Preparation of stock solutions, culture media, cryoprotectant solutions and regrowth media, Isolation of explants and *in vitro* culturing in growth retarding media for slow growth conservation, meristem isolation in dicots and monocots;
- Pretreatments, preculturing, cryoprotectant treatments varying temperature and durations, cold hardening- plants and explants, cryopreservation techniques-encapsulation-dehydration, vitrification, encapsulation-vitrificaion, droplet freezing, thawing- slow and fast, recovery and regrowth- media, light conditions;
- *In vitro*-cryo-genebanking and database management, morphological and molecular markers for assessing genetic stability-demonstration.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Advanced conservation techniques including biotechnological tools would be learnt by students.

X. Suggested Reading

Barbara MR, Chin HF and Normah MN. 2013. Conservation of Tropical Plant Species. Springer.

Bewley JD and Black M. 1994. *Seeds Physiology of Development and Germination*, Second Edition. Plenum Press, New York and London.

Chaudhury R and Malik SK. 2017. *Cryopreservation of Plant Species: Practical Approaches from Handling to Cryobanking*. ICAR-NBPGR, New Delhi. 52 p.

Chaudhury R, Pandey R, Malik SK, Bhag Mal (eds). 2003. *In vitro* Conservation and Cryopreservation of Tropical Fruit Species. IPGRI Office for South Asia, New Delhi, India/ NBPGR, New Delhi, India, 293 pp.

Cromarty A. 1984. Techniques of drying seeds, pp 88-125. *Seed Management Techniques for Genebank* (JB Dicke, S Linington and JT Williams, eds). International Board on Plant Genetic Resources, Rome.

Cromarty A, Ellis RH and Robert EH. 1982. *The Design of Seed Storage Facilities for Genetic Conservation*, Revised 1985. International Board on Plant Genetic Resources, Rome.

Ellis RH, Hong TD and Roberts EH. 1985a. Handbook of Seed Technology for Genebank Volume II. Principles and Methodology. International Board for Plant Genetic Resources, Rome.

Ellis RH, Hong TD and Roberts EH. 1985b. Handbook of Seed Technology for Genebank Compendium of Specific Germination Information and Test Recommendations. International Board for Plant Genetic Resources, Rome.

Ellis RH. 1988. The viability equation, seed viability monographs, and practical advice on seed storage. *Seed Science and Technology* **16**: 29-50.

Hong TD and Ellis RH. 1996. A protocol to determine seed storage behaviour. International Plant Genetic Resources Institute IPGRI Technical Bulletin No. 1, Rome.

Mandal BB, Chaudhury R, Engelmann F, Bhag Mal, Tao KL and Dhillon BS (editors). 2003. Conservation Biotechnology of Plant Germplasm. NBPGR, New Delhi, India/ IPGRI, Rome, Italy, 293 pp.

Reed BM. 2008. Cryopreservation—Practical Considerations. In: Reed B.M. (eds) Plant Cryopreservation: A Practical Guide. Springer, New York, NY

Roberts EH. 1972. *Viability of Seeds*. Chapman and Hall, London.

I. Course Title : Phenomics and Genomics for PGR Utilization*

II. Course Code : PGR 602

III. Credit Hours : 2(1+1)

IV. Why this course ?

Utilisation of conserved germplasm all over World has been poor and needs emphasis for increasing the resilience and productivity of agricultural production systems. Students need to understand all the advanced techniques in phenotyping and genotyping to be able to exploit the PGR.

V. Aim of the course

To impart theoretical and practical knowledge on recent advances in crop germplasm evaluation and use. To teach current advances in genomic technologies in use for breeding, phylogenetic analyses, understanding genetic value, facilitating germplasm selection in genebanks, and develop practical skills in phenotyping and genotyping.

VI. Theory

Unit I

Advances in phenotyping to overcome limitations in use of germplasm collections; advanced methodology of germplasm evaluation and predictive methods for identification of useful germplasm, phenomics facility, quantitative imaging techniques using remote sensing. Experimental designs, analyses of evaluation data and database management.

Unit II

Evaluation of crop germplasm for agronomic traits: Evaluation against biotic/ abiotic stresses; quality attributes and other value addition traits. Management and utilization of crop germplasm, germplasm registration, Core and minicore collections; Germplasm enhancement/ pre-breeding and use of wild relatives in crop improvement, embryo rescue method, pollen physiology and storage, integration of big data into breeding programs, harmonising agro-biodiversity conservation and agricultural development, New crops of the future, biofortified crops.

Unit III

Uses and applications of molecular markers in PGR – analysis of genetic diversity, identification of gaps in collection, molecular cytology, Establishment of core and mini-core collections using molecular markers, Identification of desirable genes and alleles, germplasm characterisation, trait mapping, genome sequencing, High throughput genotyping – GBS, association mapping studies: GWAS, molecular tagging of QTLs, FIGS.

VII. Practical

- Management and utilization of crop germplasm: Exercise for developing core set;
- Validation using molecular markers;
- Evaluation of crop germplasm for value addition;
- Evaluation of crop germplasm against biotic/ abiotic stresses;

- Evaluation of germplasm for quality traits;
- Biochemical/ Molecular characterisation of germplasm.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students would be exposed to latest methodologies for characterizing the germplasm for maximum utilization

X. Suggested Reading

Brown AHD, Clegg MT, Kahler AL and Weir BS (eds.). 1990. *Plant population genetics, breeding, and genetic resources*, Sinauer Associates, USA.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The use of plant genetic resources*. Cambridge University Press.

Frankel OH and Hawks JG. 1975. *Crop genetic resources for today and tomorrow*. Cambridge University Press.

Frankel OH and Michaele ES. 1987. *Conservation and evolution*. Cambridge University Press.

Frankel R and Galun E. 1977. *Pollination mechanisms, reproduction and plant breeding*.

Genetic Data Analysis II: methods for Discrete Population Genetic Data. Sinauer Associates, Massachusetts, USA.

Griffin HG and Griffin AM. 1994. *PCR Technology: Current Innovations*. CRC Press, London.

Harlan JR. 1992. *Crops and Man* (Second Edition). American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA.

Hayward MD, Bosemak NO and Romagosa I. 1993. *Plant Breeding: Principles and Practices*. Chapman & Hall.

Holden JHN and Williams JT. 1984. *Crop genetic resources: conservation and evaluation*, IBPGR.

Hillis, D and Moritz C. 1990. Molecular Systematics. Sinauer Associates, USA.

IPGRI. 1997. Regeneration of accessions in seed collections: a decision guide: Handbook for genebanks No. 5. Karp A, Isaac PG and Ingram DS. 1998. *Molecular Tools for Screening Biodiversity – Plants and Animals*. Chapman and Hall, London.

Lynch M and Walsh B. 1998. *Genetics and analysis of quantitative traits*. Sinauer Associates, Massachusetts, USA.

Peterson WW, Marie-Noelle N and Robert JH. 2018. Role of genomics in promoting the utilization of plant genetic resources in genebanks. *Briefings in Functional Genomics* **17**(3): 198–206.

Stoskopf NC. 1993. *Plant Breeding: theory and practice*. Westview Press.Tanksley SD and Orton TJ. 1983. *Isozymes in Plant Genetics and Breeding*, Part A and B. Elsevier Science Publication, Amsterdam.

Varshney RK, Mahendar T, Aggarwal RK, *et al*. 2007. Genic Molecular Markers in Plants: Development and Applications. In: Varshney RK, Tuberosa R. (eds). *Genomics-Assisted Crop Improvement*. Dordrecht: Springer Netherlands, 13–29.

I. Course Title : Economic Botany and Crop diversification*

II. Course Code : PGR 603

III. Credit Hours : 2(1+1)

IV. Why this course ?

Deeper understanding of origin and cultivation of all major crop plants and potential crops is essential for students.

V. Aim of the course

To apprise students about economic uses of plants including in fields such as Ethnopharma-cology as well as potential/ new commercial crops.

VI. Theory

Unit I

Structure, development and chemical constituents of plant parts- cereals, pulses and oilseeds, vegetables, fruits, nuts.

Unit II

Origin, history, evolution, domestication, botany, genetic resources activities, cultivation, production and utilization of various crops- cereals, pulses and oilseeds, vegetables, fruits, nuts, ornamental plants, underutilized plants.

Unit III

Economic uses and commercial importance of crop plants- cereals, pulses and oilseeds, vegetables, fruits, nuts, ornamental plants, underutilized plants, fodder and forage crops. Current topics on potential crops, biofortified crops, lost and neglected crops, revival of lesser known crops, the marketing of potential crops.

Unit IV

Importance of plants with respect to society and environment- Social and religious significance of plants in environmental amelioration. Case studies of massive economic gains due to use of lesser known crops/ genes in history of agriculture.

VII. Practical

- Structure, development and chemical constituents of plant parts-cereals;
- Structure, development and chemical constituents of plant parts-pulses and oilseeds;
- Structure, development and chemical constituents of plant parts-vegetables, fruits, nuts;
- Structure, development and chemical constituents of plant parts-ornamental plants, underutilized plants.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students would be prepared for understanding all crops including underutilized crops and their economic potential

X. Suggested Reading

Beryl Brintnall Simpson. 2013. *Plants in Our World: Economic Botany*. McGraw-Hill Education, 2014, New York, NY.

Beryl Brintnall Simpson, Molly Ogorzaly, Simpson Beryl. 2001. Economic Botany: Plants in Our World. Mcgraw-hill Science/ engineering/ math.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The use of plant genetic resources*, Cambridge University Press.

Burkill IH 1951-52 Habits of man and the origins of the cultivated plants of the old World. *Proceeding Linnean Society of London*, 164: 12-42.

Commercial products of India. Watt, Sir George.
Economic Botany. By Hill, Albert R
Frankel OH and Hawks JG. 1975. *Crop genetic resources for Today and Tomorrow*. Cambridge University Press.
George Watt (2014) Dictionary of Economic Products of India. Cambridge University Press. Wealth of India CSIR
Hanelt P. 2001. Institute of Plant and Genetics and Crop Plant Research (eds) *Mansfeld's encyclopedia of agricultural and horticultural crops*, vol 3. Springer, Berlin.
Harlan JR. 1992. *Crops and Man* (Second Edition). American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA
Hill Albert F. 1952. *Economic Botany: A Textbook of Useful Plants and Plant Products*, Second Edition. New York Toronto London McGraw-hill Book Company, Inc.
Kochhar SL. 2012. *Economic Botany in the Tropics*, Paperback, Fourth edition. Laxmi Publications.
Maiti RK and Singh VP. 2006. *An Introduction to Modern Economic Botany*. Eastern Book Corporation, Delhi.
Mehra KL and Arora RK. 1982. *Plant genetic resources of India: their diversity and conservation*. NBPGR, New Delhi.
Morton JF 1987. *Fruits of warm climates* Creative Resource Systems. Inc. N.C., Miami, FL.
Paroda RS and Arora RK (eds.). 1991. *Plant genetic resources: conservation and management*. NBPGR, New Delhi
Purseglove W. 1981. *Tropical Crops. Dicotyledons*. The English Language Book Society and Longman.
Purseglove W. 1981. *Tropical Crops. Monocotyledons*. The English Language Book Society and Longman.
Sturtevant's notes on edible plants. Hedrick UP.
Swaminathan MS and Jana S (eds.). 1992. *Biodiversity: implication for global food security*. Mc MIllan Press.

I. Course Title : PGR Policies and Regulatory Mechanisms
II. Course Code : PGR 604
III. Credit Hours : 1(1+0)

IV. Why this course ?

Biodiversity is regarded as a treasure under national sovereignty and hence regulatory mechanisms and PGR policies need to be understood

V. Aim of the course

To educate students about concepts and instruments of intellectual property rights, plant breeder's rights, farmer's rights, access and benefit sharing, international treaties and national legislation related to plant genetic resources.

VI. Theory

Unit I

Concept of intellectual property, need for IP protection, Dimensions and nature of IPR, conflicting community interest with private right. Forms of IPR, patents, copyright, trademark, design, trade secret/ confidential information, GI registration. Process of obtaining an IPR, World Intellectual Property Organization, Patent Cooperation Treaty (PCT).

Unit II

Plant breeder's rights, protection of plant varieties, UPOV; registration of plant varieties and essentially derived varieties, duration and effect of registration; traditional knowledge systems, farmer's rights, folklore, code of conduct, access and benefit sharing; compulsory license; plant varieties protection appellate tribunal.

Unit III

International instruments concerning agro-biodiversity, Convention on Biological Diversity (CBD), FAO and global system of PGR, the International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action, TRIPS agreement and IPR protection of life forms, geographical appellations. Patent Information Search, Patent Drafting, Opinion on Patentability, Patent Infringement.

Unit IV

Multilateral agreement on trade in goods – relevance to agriculture, Agreement on Agriculture (AOA); agreement on application of sanitary and phytosanitary measures (SPS), international plant protection convention, agreement on Technical Barriers to Trade (TBT). Plant quarantine, biosafety related issues.

Unit V

National legislations related to biodiversity conservation and IPR protection.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students would be able to understand the intricacies of PGR policies and do patent search.

X. Suggested Reading

Anonymous. *Providing Protection For Plant Genetic Resources: Patents, Sui Generis Systems and Biopartnerships*. Kluwer Academic Press, ISBN: 9041188754; Distributer: Landmark Ltd.

Kate KT and Laird SA. 1999. *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit Sharing*. Earthscan, London.

Michael M. *et al.* 2005. *Valuation and Conservation of Biodiversity: Interdisciplinary Perspectives on the Convention on Biological Diversity*. Springer.

Srivastava SK. 2016. *Commercial Use of Biodiversity: Resolving the Access and Benefit Sharing Issues*. SAGE Publications, India, Pvt. Ltd.

e-resources

http://www.icar.org.in/files/reports/other-reports/icar-ipmttcguide.pdf
http://www.wto.org
http://www.geographicindications.com
http://www.cbd.int www.patentoffice.nic.in
http://www.uspto.gov
http://www.wipo.int
http://www.nif.org.in
http://www.fao.org/Legal/treaties/Treaty-e.htm
http://www.plantauthority.gov.in
http://www.nbaindia.org

I. Course Title : Molecular Population Genetics in PGR Management

II. Course Code : PGR 605

III. Credit Hours : 3(2+1)

IV. Why this course ?

The genomic revolution has generated detailed population genetic data. Big data samples of complete genome sequences of many individuals from natural populations of many species have transformed population genetics inferences on samples of loci to population genomics: the analysis of genome-wide patterns of DNA variation within and between species. Molecular analyses of this is essentially to be taught to students.

V. Aim of the Course

Students would be provided insights into organization and structure of genetic variation in plant populations and practical skills in molecular diversity analyses.

VI. Theory

Unit I

The genetic structure of populations – Genetic transmission in populations, the Hardy-Weinberg principle and estimating allele frequencies, testing of departures from Hardy-Weinberg proportions, inbreeding and self-fertilization, analyzing the genetic structure of populations: Bayesian F-statistics, Nei'sGst, Weir & Cockerham's, the Wahlund Effect and Wright's F-statistics.

Unit II

Natural selection, genetic drift, mutations – The genetics of natural selection, estimating viability, Selection at one locus with many alleles, fertility selection and sexual selection, Selection component analysis, genetic drift- mutation, migration and genetic drift, selection and genetic drift; the coalescent.

Unit III

Quantitative genetics – introduction to quantitative genetics, resemblance among relatives, partitioning variance, evolution of quantitative traits, simultaneous evolution of several quantitative traits, mapping quantitative trait loci, introduction to linkage disequilibrium and association analysis.

Unit IV

Molecular evolution – introduction to molecular population genetics, the neutral theory of molecular evolution, patterns of nucleotide and amino acid substitutions, detecting selection on nucleotide polymorphisms; patterns of selection on nucleotide polymorphisms, Tajima's D, Fay's and Wu's H, and Zeng et al's E, introduction to population genomics and challenges.

Unit V

Evolution in multigene families, phylogeography, analysis of molecular variance (AMOVA), nested clade analysis, basics of cladistic analysis.

VII. Practical

- Calculating gene and genotypic frequencies;
- Testing of HWE;
- Estimation of allele frequencies under forces of selection, mutation and migration;
- Calculation of inbreeding coefficient;

- Estimation of linkage disequilibrium;
- Quantifying genetic variation at the molecular level, analysis of molecular variance;
- Hypothesis testing in molecular evolution, estimation of evolutionary parameters.

VIII. Teaching methods

- Lectures
- Power point presentations
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students will be well versed with basics of variations and molecular diversity analyses

X. Suggested Reading

Cutter AD. 2019. *A Primer of Molecular Population Genetic*. Oxford University Press.
Hartl DL and Clark AG. 2006. *Principles of Population Genetics*, 4th Ed. Sinauer Associates, Sunderland, MA.
Matthew B. Hamilton. 2009. *Population Genetics*, 1st Ed. Wiley-Blackwell.
Matthew W. Hahn. 2018. *Molecular Population Genetics*, Oxford University Press.
Casillas S and Barbadilla A. 2017. *Molecular Population, Genetics* **205**: 1003–1035.

I. Course Title : Plant Taxonomy, Ecogeography and Ecology
II. Course Code : PGR 606
III. Credit Hours : 2(1+1)

IV. Why this course ?

Students need to understand all the recent advances in plant taxonomy for understanding crop evolution and future prospects with respect to variable ecologies.

V. Aim of the course

To educate students about interdisciplinary scientific study of the distributions, abundance and relations of organisms and their interactions with the environment, and the study of ecosystems. To provide information on ecogeographic surveys, sampling strategies and legal issues involved in germplasm collecting. To teach taxonomic databases and documentation systems.

VI. Theory

Unit I

Origin and diversity of life, speciation, biosystematics, basic elements of plant ecology, ecological components, population ecology- populations and life history, growth and limits. Community ecology- species interactions, role of interactions and structure.

Unit II

Ecosystems- concept of ecosystems, ecological balance, vegetation dynamics, productivity and nutrient cycling. Conservation ecology, seed ecology, nature conservation and environmental management, ecosystem restoration, biogeography and evolution. Biodiversity functioning- genetic adaptations, population irruptions/ crisis in nature, community change and ecosystem regulation. Biodiversity conservation-geographical patterns in biodiversity, habitat fragmentation and conservation areas. Biodiversity management and exploitation-biodiversity resources and their harvesting, impact of physical and biotic factors on sustainability- case studies, impact of biotic and climatic factors on biomes and biodiversity- pollution and over-exploitation.

Unit III

Genetic diversity of PGR, genetic principles of diversity and its distribution. Indicators of diversity, assessing the threats of genetic erosion; eco-geographic surveys: planning, collection and analysis of eco-geographic data, outputs of eco-geographic surveys.

Unit IV

Differentiation and evolution of species and biosystematics, Modern evidences: morphology and anatomy; embryology and palynology; Modern evidences: Biogeography and Cytotaxonomy; Modern evidences: Comparative studies on phytochemistry, Chemo-taxonomy; Molecular taxonomy; Hybrids, domesticated species, wild-cultivated continuum.

Unit V

Sampling strategies theory and practice, strategies for wild species; Germplasm collecting: legal issues and the FAO code of conduct, participatory approaches to collecting including indigenous knowledge, Traditional knowledge systems. Taxonomic databases and documentation systems.

VII. Practical

- Concepts and methods for computing biodiversity, Alpha and beta models, calculation of species richness and endemism;
- Field visits to protected areas- biospheres/ national parks, understanding various ecosystems;
- Geospatial analysis and use of GIS;
- Identification and learning the use of CWRs of various families, survey of local biodiversity (field study), ecological status of various species (field study);
- Population and community patters- case studies on local flora;
- Identification of alien species and their impact assessment, study of protected areas, restoration of threatened and native species, bioresources and their harvesting, classical and modern species concepts and biosystematics, morphology and anatomy;
- Comparative studies on phytochemistry, chemotaxonomy, floristic and monographic work;
- Practical methods for elucidating and proving hypotheses relating to plant speciation, Numerical taxonomy-practice and procedures; biosystematic studies and their role in improving plant taxonomies, infraspecific categories in relation to population biology, taxonomic databases, wild-cultivated continuum, problems and their resolution, newer methods of analysis and interpretation.

VIII. Teaching methods

- Lectures
- Power point presentations
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Complete understanding of taxonomic principles for PGR handling

X. Suggested Reading

Ananthakrishanan. 1989. *Bioresource ecology*, Oxford & IBH Pub. Co. (New Delhi).

Brummitt RK and Powell CE. 1992. *Authors of Plant Names*. Royal Botanic Gardens, Kew, London, UK. 732 p.

Hermann R. 1980. *Ecology: a text book*. Springer.

Heywood VH. 1973. *Taxonomy and Ecology*. Academic Press London.

Hollingsworth PM, Bateman RM and Gornall RJ (eds.). 1999. *Molecular Systematics and Plant Evolution*. Taylor and Francis, London and New York. 485 p.

Iriondo *et al*. 2008. *Conserving Plant Genetic Diversity in Protected Areas: Population management of CWR*. CAB International, Wallingford, UK.

Kumar HD. 1992. *Modern concepts of ecology*. Vikas Publishing House (New Delhi),

Meffe and Carroll 1997. *Principles of Conservation Biology*, 2nd edition. Publisher: Sinauer Associates.

Paroda RS and Arora RK (eds.) 1991. *Plant genetic resources: conservation and management*. NBPGR, New Delhi.

Swaminathan MS and Jana S (eds.). 1992. *Biodiversity: implication for global food security*. McMIllan Press.

Trehane P, Bricknell CD, Baum BR, Hetterscheid WLA, Leslie AC, McNeill J, Spongberg SA and Vrugtman F. 1995. *The International Code of Nomenclature for Cultivated Plants Regnum Veg*. 133. Quarterjack Publishing, Wimborne, UK. 175 p.

Vavilov NI 1887-1943. Origin and Geography of Cultivated Plants. English ed.: Translated by Love, D. 1992. Camb. University Press, Cambridge, UK. 498 p.

Watt G 1889-1896. *A Dictionary of Economic Products of India*. 7 vols., Repr. 1972. Calcutta, India.

Woodbury AM. 1954. *Principle of general ecology*. Blakiston, New York.

I. Course Title : *In situ On-farm* conservation

II. Course Code : PGR 607

III. Credit Hours : 2(1+1)

IV. Why this course ?

One of the alternatives to agrobiodiversity conservation which is dynamic in nature needs understanding

V. Aim of the course

To impart knowledge about *in-situ* and/ *On-farm* conservation of crop diversity and type of information required for such an approach.

VI. Theory

Unit I

Conservation strategies (*in-situ*, *Ex-situ* community conservation), *In situ* conservation of wild species in nature reserves, *In situ* conservation of crop diversity on-farm.

Unit II

Phytogeographic surveys and inventory, estimation of genetic diversity, population biology, concept of minimum viable population, population viability and population genetics theory, designation of gene management zones (GMZs)/ gene sanctuaries, management and monitoring of GMZs, threat of genetic erosion, conservation agency priorities, biologically important species, National action plan for agrobiodiversity, Delhi Declaration on Agrobiodiversity.

Unit III

Social, cultural and economic factors influencing crop genetic diversity, Agro-ecosystem factors: natural and farmer-managed, agromorphological characters, farmer selection and maintenance, the genetics structure of crop landraces and the challenge to conserve them *in situ* on-farms, seed systems: formal vs informal.

Unit IV

Institutional frameworks for the implementation of on-farm conservation, identification of target crops, site selection, community sensitization, participatory plant breeding, sampling, structuring, documentation and presenting information for action plans, increasing crop genetic diversity's competitiveness for farmers, improvising the material and farmers 'access to genetic materials, increasing consumer demand, the role of policy, deciding on an appropriate initiative, evaluating benefit-enhancement options, role of Geographical Indications (GI) in agri-horticultural crops.

VII. Practical

- Floristic surveys and inventory (wild species in nature reserves and crop species in traditional agro-ecosystems), questionnaire preparation;
- Visit to commercial units processing native crops, and to on farm fields and to community seed banks in villages;
- The genetic structure of crop landraces and the challenge to conserve them *in situ* on-farm at selected sites.

VIII. Teaching methods

- Lectures
- Power point presentations
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Students will understand the current status of this method

X. Suggested Reading

Brush SB 1999. *Genes in the field: On-farm Conservation of Crop Diversity*. Lewis Publishers, Boca Raton, Florida, USA.

Jarvis D I, Meyer L, Klemick, H, Guarino, L, Smale M, Brown, AHD, Sadiki, M and Sthapit B. 2000. A Training Guide for *In situ* Conservation On-farm. Version 1. International Plant Genetic Resources Institute, Rome, Italy.Maxted N, Dulloo ME, Ford-Lloyd BV (eds.). 2016. Enhancing Crop Genepool Use: Capturing Wild Relative and Landrace Diversity for Crop Improvement. CAB International, Wallingford, UK.

Jarvis D, Hodgkin T, Brown AHD, Tuxill JD, Loìpez Noriega I, Smale M, Shtapit B, Samper S. 2016. Crop Genetic Diversity in the Field and on the Farm. Principles and Applications in Research Practices. Yale Agrarian Studies Series. Bioversity International, Maccarese/ Swiss Agency for Development and Cooperation (SDC), Bern/ Yale University Press, New Haven.

Maxted N, Dulloo ME, Ford-Lloyd BV, Frese L, Iriondo JM, Pinheiro de Carvalho MAA (eds.). 2012. Agrobiodiversity Conservation: Securing the Diversity of Crop Wild Relatives and Landraces. CAB International, Wallingford.

Maxted N, Guarino L, Myer L, Chiwona EA. 2002. Towards a methodology for on-farm conservation of plant genetic resources. *Genetic Resources and Crop Evolution* **49**: 31-46.

Vernoy, R, Shrestha P and Sthapit B. 2015. *Community Seed Banks: Origins, Evolution and Prospects*. Oxford, Routledge.

I. Course Title : Genomic Tools and Current Applications

II. Course Code : PGR 608

III. Credit Hours : 3(2+1)

IV. Why this course ?

Plant genomics aims to develop high-throughput genome-wide-scale technologies, tools and methodologies to elucidate the basics of genetic traits/ genetic diversity in organisms

V. Aim of the course

To provide knowledge in genomic tools and their application in plant genetic resource exploration, collection, conservation and utilization.

VI. Theory

Unit I

Genomics: Basic concept, structural, comparative and functional genomics, genomic tools, TILLING, EcoTILLING, Genome duplication and ploidy variation, application of genomic tools in PGR valuation, conservation and utilization.

Unit II

DNA barcoding: Basic concept, methodologies, utility of DNA barcoding in species delineation, plant exploration and collection, conservation and utilizing species in widening gene pool of major crops.

Unit III

DNA markers: Types, application in assessment of diversity in germplasm, DNA fingerprinting and genetic identity analysis, allele mining, development and validation of core sets, genetic association studies and genomic selection in germplasm collections.

VII. Practical

- Gene based screening of trait-specific germplasm using linked molecular markers;
- Amplification and sequencing of DNA barcoding loci for species identification in crops;
- Allele mining in trait-specific germplasm for quality traits in crops;
- DNA fingerprinting for identity analysis in crops, molecular markers for designation and validation of germplasm core-sets.

VIII. Teaching methods

- Lectures
- Power point presentations
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

Knowledge on current state-of-the-art technological developments of genomics era, current challenges and handling methods

X. Suggested Reading

Fleury D, Jefferies S, Kuchel H and Langridge P. 2010. Review Paper: Genetic and genomic tools to improve drought tolerance in wheat. *Journal of Experimental Botany* **61**: 3211–3222.

Gupta PK, Kulwal PL and Jaiswal V. 2014. Association Mapping in Crop Plants: Opportunities and Challenges: *Advances in Genetics* **85**: 109-147.
Henry R (ed.) 2013. *Molecular Markers in Plants*. Wiley and Blackwell Publication, Iowa USA, 196 p.
Pérez-de-Castro AM, Vilanova S, Cañizares J, *et al*. 2012. Application of genomic tools in plant breeding. *Current Genomics* **13**: 179-195.
Primrose SB and Twyman RM. 2006. *Principles of Gene Manipulation and Genomics: Part III Genome Analysis, Genomics, and Beyond.* 7th Edition, Blackwell, Malden, USA, pp. 323-481.
Sucher NA, Hennell JR and Carles MC (eds.) 2012. *Plant DNA Fingerprinting and Barcoding: Methods and Protocols*. Humana Press, Springer Science, New York, 201 p.
Tuberosa R, Graner A and Frison E (eds.) 2014. *Genomics of Plant Genetic Resources, Volume 1. Managing, Sequencing and Mining Genetic Resources*. Springer Science, New York, 825 p.
Varshney RK and Tuberosa R (eds.) 2007. *Genomics-Assisted Crop Improvement Vol 2: Genomics Applications in Crops*. Springer Dordrecht, The Netherlands, 509 p.

I. Course Title : Intellectual Property Rights and Regulatory Mechanisms*

II. Course Code : PGR 609

III. Credit Hours : 1(1+0)

IV. Why this course ?

Biodiversity conservation and its judicious utilization are important in sustainable plant breeding programs. Breeders' and farmers' rights are important in scenario of globalization of agriculture so knowledge of IPRs is essential for a plant breeder to protect his varieties.

V. Aim of the course

To educate students about concepts and instruments of intellectual property rights, plant breeder's rights, farmer's rights, access and benefit sharing, international treaties and national legislation related to plant genetic resources.

VI. Theory

Unit I

Concept of intellectual property, need for IP protection, Dimensions and nature of IPR, conflicting community interest with private right. Forms of IPR, patents, copyright, trademark, design, trade secret/ confidential information, GI registration. Process of obtaining an IPR, World Intellectual Property Organization, Patent Cooperation Treaty (PCT).

Unit II

Plant breeder's rights, protection of plant varieties, UPOV; registration of plant varieties and essentially derived varieties, duration and effect of registration; traditional knowledge systems, farmer's rights, folklore, code of conduct, access and benefit sharing; compulsory license; plant varieties protection appellate tribunal; finance, accounts and audit; infringement, offenses, penalties and procedure.

Unit III

International instruments concerning agro-biodiversity, Agenda 21, Convention on Biological Diversity (CBD), FAO and global system of PGR, the International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action, TRIPS agreement and IPR protection of life forms, geographical appellations.

Unit IV

Multilateral agreement on trade in goods – relevance to agriculture, Agreement on Agriculture (AOA); agreement on application of sanitary and phytosanitary measures (SPS Agreement), international plant protection convention, agreement on technical barriers to trade (TBT); Plant quarantine, biosafety related issues.

Unit V

National legislations related to biodiversity conservation and IPR protection, Patent Information Search, Patent Drafting, Opinion on Patentability, Patent Infringement

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks

IX. Learning Outcome

All current aspects on IPRs, plant breeder's rights, farmer's rights, access and benefit sharing, international treaties and national legislation would be understood.

X. Suggested Reading

Kate KT and Laird SA. 2002. *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit Sharing*. Earthscan.

Markussen M *et al*. 2005 Valuation and Conservation of Biodiversity: Interdisciplinary Perspectives on the Convention on Biological Diversity, Springer.

Marin PLC. 2002. *Providing Protection For Plant Genetic Resources: Patents, Sui Generis Systems And Biopartnerships*. Publisher: Kluwer Law International, ISBN: 9041188754; Distributer: Landmark Ltd.

e-Resources

http://www.icar.org.in/files/reports/other-reports/icar-ipmttcguide.pdf
http://www.wto.org;
http://www.geographicindications.com;
http://www.cbd.int;
http://www.patentoffice.nic.in;
http://www.uspto.gov;
http://www.wipo.int;
http://www.nif.org.in;
http://plantauthority.gov.in
http://nbaindia.org

ANNEXURE I

List of BSMA Committee Members for Plant Science

(Genetics and Plant Breeding/ Seed Science and Technology/ Plant Genetics Resources)

Name	Address	Specialization
Dr Z.S. Solanki Former Vice-Chancellor	Agriculture University, Kota (Rajasthan) Present Address: 2/8 Suswani Mata Colony Mandore, Jodhpur-342 304, Rajasthan zssolanki@gmail.com Mob.: 09481029482	Chairman
Dr Bhabendra Baisakh Professor & Head	Department of Genetics and Plant Breeding Orissa University of Agriculture and Technology Bhubaneswar-751 003 bhaba4@gmail.com Mob.: 09437195452	Convener
Dr S.R. Maloo Former Director (Research) & Dean	Agriculture College Maharana Pratap University of Agriculture and Technology, Udaipur Present Address: 47, Anand Nagar Ayad Bridge University Road Udaipur-313 001 shivratan.maloo@yahoo.com Mob.: 09414169710	Genetics & Plant Breeding
Dr J.P. Sharma Professor	Department of Plant Breeding and Genetics-cum-Director Research, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu-180 009 jpsdr2015@gmail.com Mob.: 09419134737	Genetics & Plant Breeding
Dr S. Sundareswar Professor	Department of Seed Science & Technology Tamilnadu Agricultural University Coimbatore-641 003 sundarseeds@gmail.com Mob.: 09442020149	Seed Science & Technology
Rekha Chaudhary Professor	National Bureau of Plant Genetic Resources New Delhi-110 012 Rekha.chaudhary@gmail.com rscientist58@gmail.com Mob.: 09871101592	Plant Genetics Resources

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 1

Plant Protection

- Entomology
- Plant Pathology
- Nematology

Contents

Acknowledgements

BSMA Committee for Plant Protection thanks Dr Arvind Kumar, Chairman, National Core Group and Vice-Chancellor, Rani Laxmi Bai Central Agricultural University, Jhansi for his mentorship and guidance throughout. Dr K.M. Bujarbaruah, Dr M.S. Nataraj, Dr N.C. Patel, Dr Pradeep Kumar Bisen, respectively, Vice-Chancellors of Assam Agricultural University, University of Agricultural Sciences, Bengaluru, Anand Agricultural University and Jawaharlal Nehru Krishi Vishwa Vidyala, Jabalpur reserve our gratitude and appreciation for having hosted our meetings and workshops involving all the stake- holders in higher agricultural education. The Committee is also indebted to Dr N.S. Rathore, the erstwhile DDG (Education) and Dr G. Venkateshwarlu, ADG (EQR), ICAR for providing input and all the administrative support.

Dr A.K. Bhowmick
Convener

Dr S. Lingaraju
Chairman

Preamble

(Plant Protection)

The BSMA Committee on Plant Protection meticulously deliberated upon the issues to ameliorate the overall agricultural education programme, and plant protection in particular. The curricula and syllabi of the three disciplines, viz., Entomology, Plant Pathology and Nematology, were discussed in the meetings and workshops convened by the BSMA Committee on Plant Protection. The opinions and suggestions invited from institutions, eminent scientists, and other stakeholders (private entrepreneurs, governmental and non-governmental organizations) were reviewed by the Committee. The modified post-graduate programme in Plant Protection has been designed to meet out the demands of private sector, advanced research and applications, supplementary practical skills required, and to enhance national and global competence and employability of our students.

The Master's and Doctoral programmes retain the fundamental aspects, e.g. morphology, taxonomy, physiology, biology/ bionomics and ecology (analogous to learning the basic *ragas* in Indian classical music to excel in music) besides covering the applied aspects of beneficial biota, be they insects, nematodes, fungi or bacteria), their commercial utilization, pest/ pathogen spectrum of specific crops and their management. Various current issues and latest approaches in the subject of Entomology, Plant Pathology and Nematology have been given a new thrust. Aiming at improving the theoretical and practical knowledge of the postgraduate students in their respective subjects the number of Masters courses have been increased from 20 (in the previous dispensation) to 23 in Entomology; and from 14 to 15 in Nematology with considerable credit load on the practical aspects. At the doctoral level, impetus has been given to research work. Certain courses have been merged if the syllabi in them were found overlapping.

- *Entomology*. Some of the salient features of the revised curriculum at the Master's level include: emphasis on molecular approaches and nanotechnology in entomology; molecular systematics; understanding host plant resistance and breeding for pest resistant crop cultivars; ecological engineering/ farmscaping for pest management in conventional and organic farming systems; besides an independent course on integrated management of pest/ disease situations (insects, mites, diseases and nematodes) in protected cultivation; independent, advanced training in edible and therapeutic insects; medical and veterinary entomology; sericulture, apiculture and lac culture to encourage location-specific self-employment *vis-à-vis* enhancing farm income; detailed study on post-harvest losses due to insects, mites and vertebrate pests, and their management; an elaborate exposure to plant quarantine, bio-safety and bio-security in view of the rising invasive insect pest infestations and repercussions of climate change. These aspects have been included in the Master's curriculum itself keeping in view of the invasive, exotic pest infestation records as also with a view to cover the details of Indian Biodiversity Act. The course on Commercial Entomology has been split into three separate courses (Apiculture, Sericulture and Lac Culture) to give wider scope for location-specific self employment, as envisaged in the National Educational Policy and towards enhancement of farmer's income. At the Doctoral level, the coverage of different courses, both theoretical and practical, has been reduced with a view to enable the scholars concentrate on their research work towards achieving significant transferable technologies.

- *Plant Pathology*. Two Master's programme courses have been done away with, viz., Mushroom Production Technology and Insect Vectors of Plant Viruses and other Pathogens. The erstwhile nomenclature of the (masters and doctoral) courses on Bacteria is changed to 'Plant Pathogenic Prokaryotes' and 'Advances in Plant Pathogenic Prokaryotes', respectively. Since the exploitation of Botanicals for the pathogens' suppression and the disease management is gaining ground, the aspects pertaining to them find a place in a course. A course on Plant Nematology is made a compulsory course at master's level.
- *Nematology*. The contents of each course have been considerably refurbished in line with the developments. Considering the growing realization that plant nematodes are a major biotic constraints in the cultivation of crops raised under protected cultivation regimes, a new course on IPM in Protected Cultivation has been formulated: the same has been cross-listed with Entomology and Plant Pathology.

The reader of this note can see that this preamble is meant to give a bird's view about our BSMA Committee's recommendations *vis-a-vis* the three disciplines of Entomology, Plant Pathology and Nematology. The 'Courses at a Glance' provided in the beginning of each discipline will instantly tell the changes from the previous dispensation of 2009 (the first BSMA effort). There is no gainsaying the fact that the syllabi of each course may be consulted for a larger use.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Protection
– Entomology

Preamble
(Entomology)

Plant improvement has a long history for its growth and development. Plant breeding became established as a science in the twentieth century following the rediscovery of Mendel's laws of inheritance. Nearly 50% of global increase in food production is attributed to plant breeding. Since genetic improvement in an inherent feature, products of plant breeding can have wide global impact as exemplified by the Green Revolution for wheat and rice varieties of 1960s or transgenic crops of recent decades. Therefore developing sufficient human resources in Genetics and Plant Breeding with advanced knowledge and technical skill will further elevate the agricultural sector to attain a new peak in increasing food production matching the requirement of population.

Present agriculture research and international market demand the need for specialised human resource for teaching cutting edge technology with application of biotechnology, nanotechnology, artificial intelligence in crop improvement, increasing entrepreneurship etc, would warrant students to have strong knowledge of practical and management skills which will help them to face the competitiveness in public and private sector.

Hence, restructuring of course curricula and delivery system to match with the present situation is the need of the time. In this proposed revision of curriculum in Genetics and Plant Breeding, the BSMA sub-group organized a series of meetings and electronic media-led consultations to develop a set of courses suitable for M.Sc. and Ph.D. students of the discipline.

The meetings were focussed on the basic principles as well as the innovative developments in Genetics and Plant Breeding, as the platform building status of Plant Sciences. Built on this platform with the latest state of the art technologies including biotechnology and molecular biology will enable a complete coverage of the subjects. The basic courses have therefore been kept as compulsory courses which need to be taken by all the students irrespective of the subject specialization or stream from which they entered into PG education.

The BSMA Committee had thread bare discussions over four sessions on the topical issues concerning Genetics and Plant Breeding, Seed Science and Technology and Plant Genetic Resources. The curricula and syllabi of all these disciplines were discussed at length in the meetings and workshops. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the committee. The new look and restructured PG programmes in Genetics and Plant Breeding have been designed in considerations based on demands of private sector harnessing commercial aspects, modern research tools and their applications, supplementary skills required, and to enhance the global competitiveness and employability of our students. Considerable efforts have, therefore gone in for the preparation of this document.

Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and social need both at national and international level areMolecular Breeding and Bioinformatics, Breeding for Quality and Special Traits, Seed Production and Certification, Breeding Vegetable Crops, Breeding Fruit Crops, Breeding Ornamental Crops for M.Sc. and IPR and Regulatory Mechanism (e-course) as well as Population Genetics for Ph.D. programme.

Course Title with Credit Load
M.Sc. (Ag) in Plant Protection - Entomology

Course Code	Course Title	Credit Hours
ENT 501*	Insect Morphology	3 (2+1)
ENT 502*	Insect Anatomy and Physiology	3 (2+1)
ENT 503*	Insect Taxonomy	3 (1+2)
ENT 504*	Insect Ecology	3 (2+1)
ENT 505*	Biological Control of Insect Pests and Weeds	3 (2+1)
ENT 506*	Toxicology of Insecticides	3 (2+1)
ENT 507	Host Plant Resistance	2 (1+1)
ENT 508*	Concepts of Integrated Pest Management	2 (2+0)
ENT 509*	Pests of Field Crops	3 (2+1)
ENT 510*	Pests of Horticultural and Plantation Crops	3 (2+1)
ENT 511*	Post Harvest Entomology	2 (1+1)
ENT 512	Insect Vectors of Plant Pathogens	2 (1+1)
ENT 513	Principles of Acarology	2 (1+1)
ENT 514	Vertebrate Pest Management	2 (1+1)
ENT 515	Techniques in Plant Protection	1 (0+1)
ENT 516	Apiculture	3 (2+1)
ENT 517	Sericulture	3 (2+1)
ENT 518	Lac Culture	3 (2+1)
ENT 519	Molecular Approaches in Entomology	3 (2+1)
ENT 520	Plant Quarantine, Biosafety and Biosecurity	2 (2+0)
ENT 521	Edible and Therapeutic Insects	2 (1+1)
ENT 522	Medical and Veterinary Entomology	2 (1+1)
ENT 523	Forest Entomology	2 (1+1)
ENT 591	Master's Seminar	1 (0+1)
ENT 599	Master's Research	30 (0+30)

*Compulsory Major Courses

Course Contents
M.Sc. (Ag) in Plant Protection-Entomology

I. Course Title : Insect Morphology
II. Course Code : ENT 501
III. Credit Hours : 3 (2+1)

IV. Aim of the course

To acquaint the students with the external morphology of the insect's body and the functioning of various body parts.

V. Theory

Unit I

External Morphology: Insect body wall structure, cuticular outgrowths, colouration and special integumentary structures in insects, body tagmata, sclerites and segmentation.

Head- Origin, structure and modification; mouthparts, antennae, their types and functioning; tentorium and neck sclerites.

Thorax- Areas and sutures of tergum, sternum and pleuron, pterothorax; wings: structure and modifications, venation, wing coupling apparatus and mechanism of flight; legs: structure and modifications.

Abdomen- Segmentation and appendages; genitalia and their modifications; embryonic and post-embryonic development.

Unit II

Insect sense organs (mechano-, photo- and chemo- receptors); organogenensis at pupal stage; insect defense; chaetotaxy; morphological traits in relation to forensic entomology.

Unit III

Types of immature stages in insect orders, morphology of egg, nymph/ larva and pupa, identification of different immature stages of crop pests and stored product insects. Comparative study of life history strategies in hemi-metabola and holometabola, immature stages as ecological and evolutionary adaptations, significance of immature stages for pest management.

VI. Practical

- Preparation of permanent mounts of different body parts and their appendages of taxonomic importance including male and female genitalia;
- Dissection of genitalia. Types of immature stages in insects; their collection, rearing and preservation;
- Identification of immature insects to orders and families, in endopterygote orders, viz., Diptera, Lepidoptera, Hymenoptera and Coleoptera using key;

VII. Learning outcome

- Students are expected to have a complete understanding of the comparative morphology of the external features of insects that can be utilized in taxonomy, ecology and applied entomology.

VIII. Suggested Reading

Chapman RF. 1998. *The Insects: Structure and Function*. Cambridge Univ. Press, Cambridge.
Chu HF. 1992. *How to Know Immature Insects*. William Brown Publication, Iowa.
Duntson PA. 2004. *The Insects: Structure, Function and Biodiversity*. Kalyani Publishers, New Delhi.
Evans JW. 2004. *Outlines of Agricultural Entomology*. Asiatic Publ., New Delhi.
Gillott C. 1995. *Entomology*, 2nd Ed. Plenum Press, New York, London.
Gullan PJ and Cranston PS. 2000. *The Insects, An Outline of Entomology*, 2nd Ed. Blackwell Science, UK.
Peterson A. 1962. *Larvae of Insects*. Ohio University Press, Ohio.
Richards OW and Davies RG. 1977. *Imm's General Text Book of Entomology*. 10th Ed. Chapman and Hall, London.
Snodgross RE. 1993. *Principles of Insect Morphology*. Cornell Univ. Press, Ithaca.
Tembhore DB. 2000. *Modern Entomology*, Himalaya Publishing House, Mumbai.
Stehr FW. 1998. *Immature Insects*. Vols. I, II. Kendall Hunt Publication, Iowa.

I. Course Title : Insect Anatomy and Physiology
II. Course Code : ENT 502
III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart knowledge about the anatomy and physiology of insect body systems; nutritional physiology; and their applications in entomology.

V. Theory

Unit I

Scope and importance of insect physiology; physiology of integument, moulting, chemistry of cuticle, biosysthesis of chitin; growth, hormonal control, metamorphosis and diapause; pheromone secretion, transmission, perception and reception.

Unit II

Physiology and mechanism of digestion, circulation, respiration, excretion, reproduction, secretion (exocrine and endocrine glands) and nerve impulse transmission in insects.

Unit III

Importance of insect nutrition- role of vitamins, proteins, amino acids, carbohydrates, lipids, minerals and other food constituents; extra and intra-cellular microorganisms and their role in physiology; artificial diets.

VI. Practical

- Latest analytical techniques for analysis of free amino acids of haemolymph;
- Determination of chitin in insect cuticle;
- Examination and count of insect haemocytes; preparation and evaluation of various diets;
- Consumption, utilization and digestion of natural and artificial diets.

VII. Learning outcome

- Students are expected to have a thorough understanding of insect growth and development, physiology of exoskeleton, endoskeleton and different organ systems;

action and role of hormones, pheromones, physiology of nutrition and its application.

VIII. Suggested Reading

Chapman RF. 1998. *Insects: Structure and Function*. ELBS Ed., London.
Duntson PA. 2004. *The Insects: Structure, Function and Biodiversity*. Kalyani Publishers, New Delhi.
Gullan PJ and Cranston PS. 2000. *The Insects: An Outline of Entomology*, 2nd Ed. Blackwell Science, UK.
Kerkut GA and Gilbert LI. 1985. *Comprehensive Insect Physiology, Biochemistry and Pharmacology*. Vols. I-XIII. Pergamon Press, New York.
Patnaik BD. 2002. *Physiology of Insects*. Dominant Publishers, New Delhi.
Richards OW and Davies RG. 1977. *Imm's General Text Book of Entomology*. 10th Ed. Vol. 1. *Structure, Physiology and Development*. Chapman and Hall, New York.
Simpson SJ. 2007. *Advances in Insect Physiology*, Vol. 33, Academic Press (Elsevier), London, UK.
Wigglesworth VB. 1984. *Insect Physiology*. 8th Ed. Chapman and Hall, New York.

I. Course Title : Insect Taxonomy
II. Course Code : ENT 503
III. Credit Hours : 3 (1 + 2)

IV. Aim of the course

To sensitize the students on the theory and practice of classifying organisms (with special reference to animals) and the rules governing the same. To introduce the students to the classification of insects up to the level of families with hands-on experience in identifying the families of insects with an emphasis on the practical aspects.

V. Theory

Unit I

History of insect classification; principles of systematics and its importance. Identification, purpose, methods character matrix, taxonomic keys. Descriptions-subjects of descriptions, characters, nature of characters, analogy *v/s* homology, parallel *v/s* convergent evolution, intraspecific variation in characters, polythetic and polymorphic taxa, sexual dimorphism. Brief evolutionary history of insects-introduction to phylogeny of insects and Classification of Superclass Hexapoda – Classes – Ellipura (Collembola, Protura), Diplura and Insecta- and the Orders contained. International Code of Zoological Nomenclature, Phylocode, its brief explanation and uses. Process of speciation and interbreeding allopatric species. Molecular systemnatics, DNA barcoding, karyological and biochemical approaches in taxonomy. Insect labeling protocols and procedures.

Unit II

Distinguishing characters, general biology, habits and habitats of insect orders and economically important families contained in them. Collembola, Protura, Diplura. Class Insecta: Subclass Apterygota – Archaeognatha, Thysanura. Subclass: Pterygota, Division Palaeoptera – Odonata and Ephemeroptera. Division: Neoptera: Subdivision: Orthopteroid and Blattoid Orders (=Oligoneoptera: Plecoptera, Blattodea, Isoptera, Mantodea, Grylloblattodea, Dermaptera, Orthoptera, Phasmatodea, Mantophasmatodea, Embioptera, Zoraptera), Subdivision: Hemipteroid Orders (=Paraneoptera): Psocoptera, Phthiraptera, Thysanoptera and Hemiptera.

Unit III

Distinguishing characters, general biology, habits and habitats of insect orders and economically important families contained in them (Continued). Division Neoptera – Subdivision Endopterygota, Section Neuropteroid- Coleopteroid Orders: Strepsiptera, Megaloptera, Raphidioptera, Neuroptera and Coleoptera, Section Panorpoid Orders Mecoptera, Siphonaptera, Diptera, Trichoptera, Lepidoptera, and Section Hymenopteroid Orders: Hymenoptera.

VI. Practical

- Study of Orders of insects and their identification using taxonomic keys;
- Keying out families of insects of different major Orders: Odonata, Orthoptera, Blattodea, Mantodea, Isoptera, Hemiptera, Thysanoptera, Phthiraptera, Neuroptera, Coleoptera, Diptera, Lepidoptera and Hymenoptera;
- Field visits to collect insects of different orders.

VII. Learning outcome

- Students are expected to know the evolution of arthropods, especially insects and other hexapods, and their hierarchical classification
- Acquire working skills for collecting, mounting, and preserving insects
- Understand the basic concepts of taxonomic hierarchy, identification, taxonomic characters, variations, taxonomic keys and preparation of taxonomic papers
- Identify insects of economic importance up to family levels, taking up the insect orders of agriculture and veterinary importance

VIII. Suggested Reading

CSIRO 1990. *The Insects of Australia: A Text Book for Students and Researchers*. 2nd Ed. Vols. I and II, CSIRO. Cornell Univ. Press, Ithaca.

Freeman S and Herron JC. 1998. *Evolutionary Analysis*. Prentice Hall, New Delhi.

Gullan PJ and Cranston PS. 2010. *The Insects: An outline of Entomology*. 4th Ed. Wiley-Blackwell Publications, West Sussex, UK.

Mayr E. 1971. *Principles of Systematic Zoology*. Tata McGraw Hill, New Delhi.

Richards OW and Davies RG. 1977. *Imm's General Text Book of Entomology*. 10th Ed. Chapman and Hall, London.

Ross HH.1974. *Biological Systematics*. Addison Wesley Publ. Company.

Triplehorn CA and Johnson NF. 1998. *Borror and DeLong's Introduction to the Study of Insects*. 7th Ed. Thomson/ Brooks/ Cole, USA/ Australia.

I. Course Title : Insect Ecology

II. Course Code : ENT 504

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To teach the concepts of ecology, basic principles of distribution and abundance of organisms and their causes. Study life tables, constructing life tables, organization of communities, diversity indices. Train students in sampling methodology, calculation of diversity indices, relating insect population fluctuations to biotic and/ or abiotic causes.

V. Theory

Unit I

History and definition. Basic Concepts. Organisation of the Biological world. Plato's

Natural Balance *vs* Ecological Dynamics as the modern view. Abundance and diversity of insects, Estimates and Causal factors. Study of abundance and distribution and relation between the two. Basic principles of abiotic factors and their generalised action on insects. Implications for abundance and distribution of organisms including insects- Law of the Minimum, Law of Tolerance, and biocoenosis, Systems approach to ecology.

Unit II

Basic concepts of abundance- Model *vs* Real world. Population growth basic models – Exponential *vs* Logistic models. Discrete *vs* Continuous growth models. Concepts of Carrying capacity, Environmental Resistance and Optimal yield. Vital Statistics- Life Tables and their application to insect biology. Survivorship curves. Case studies of insect life tables. Population dynamics- Factors affecting abundance- Environmental factors, dispersal and migration, Seasonality in insects. Classification and mechanisms of achieving different seasonality- Diapause (Quiescence) – aestivation, hibernation.

Unit III

Biotic factors- Food as a limiting factor for distribution and abundance, Nutritional Ecology. Food chain- web and ecological succession. Interspecific interactions- Basic factors governing the interspecific interactions- Classification of interspecific interactions – The argument of cost-benefit ratios. Competition- Lotka-Volterra model, Concept of niche ecological homologues, competitive exclusion. Evolution of mimicry, colouration, concept of predator satiation; evolution of life history strategies.

Unit IV

Community ecology- Concept of guild, Organisation of communities- Hutchinson Ratio, May's d/w, Relation between the two and their association with Dyar's Law and Przibram's law. Relative distribution of organisms, Concept of diversity- the Wallacian view. Assessment of diversity. Diversity- stability debate, relevance to pest management. Pest management as applied ecology. Climate change and insect pest/ natural enemy population; ecological engineering.

VI. Practical

- Types of distributions of organisms;
- Methods of sampling insects, estimation of densities of insects and understanding the distribution parameters- Measures of central tendencies, Poisson Distribution, Negative Binomial Distribution;
- Determination of optimal sample size. Learning to fit basic population growth models and testing the goodness of fit;
- Fitting Holling's Disc equation;
- Assessment of prey-predator densities from natural systems and understanding the correlation between the two;
- Assessing and describing niche of some insects of a single guild;
- Calculation of niche breadth, activity breadth and diagrammatic representation of niches of organisms;
- Calculation of diversity indices- Shannon's, Simpson's and Avalanche Index and understanding their associations and parameters that affect their values;
- Problem solving in ecology. Field visits to understand different ecosystems and to study insect occurrence in these systems.

VII. Learning outcome

- The students are expected to be well versed with the basic concepts of ecology, ecological succession, population ecology, community ecology, nutritional ecology and different insect-ecosystem interactions
- Quantification of insect diversity and abundance, life table analyses, predator-prey and host-parasitoid relations, functional and numerical responses, niche breadth and overlap

VIII. Suggested Reading

Begon M, Townsend CR and Harper JL. 2006. *Ecology: From Individuals to Ecosystems*. 4th Ed. Blackwell Publishing, USA/ UK/ Australia.

Chapman JL and Reiss MJ. 2006. *Ecology: Principles and Applications*. 2nd Ed. Cambridge Univ. Press, Cambridge.

Fowler J, Cohen L and Jarvis P. 1998. Practical Statistics for Field Biology. 2nd Ed. John Wiley & Sons, Chichester, West Sussex PO19 8SQ, England.

Gotelli NJ and Ellison AM. 2004. *A Primer of Ecological Statistics.* Sinauer Associates, Inc., Sunderland, MA.

Gotelli NJ. 2001. *A Primer of Ecology*. 3rd Ed. Sinauer Associates, Inc., Sunderland, MA

Gupta RK. 2004. *Advances in Insect Biodiversity*. Agrobios, Jodhpur.

Krebs CJ. 1998. *Ecological Methodology*. 2nd Ed. Benjamin-Cummings Publ. Co., New York.

Krebs CJ. 2001. *Ecology: The Experimental Analysis of Distribution and Abundance.* 5th Ed. Benjamin-Cummings Publ. Co., New York.

Magurran AE. 1988. *Ecological Diversity and its Measurement.* Princeton Univ. Press, Princeton.

Price PW. 1997. *Insect Ecology*. 3rd Ed. John Wiley, New York.

Real LA and Brown JH. (Eds). 1991. *Foundations of Ecology: Classic Papers with Commentaries.* University of Chicago Press, Chicago.

Schowalter Timothy D. 2011. *Insect Ecology – An Ecosystem Approach*. 3rd Ed. Academic Press, London, UK/ CA, USA.

Southwood TRE and Henderson PA. 2000. *Ecological Methods.* 3rd Ed. Methuen and Co. Ltd., London.

Speight MR, Hunta MD and Watt AD. 2006. *Ecology of Insects: Concepts and Application*. Elsevier Science Publ., The Netherlands.

Townsend Colin R, Begon Michael and Harper John L. 2008. *Essentials of Ecology*. 3rd Ed. Blackwell Publishing, USA/ UK/ Australia.

Wilson EO, William H and Bossert WH. 1971. *A Primer of Population Biology*. Harvard University, USA.

Wratten SD and Fry GLA. 1980. *Field and Laboratory Exercises in Ecology*. Arnold, London.

I. Course Title : Biological Control of Insect Pests And Weeds

II. Course Code : ENT 505

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To train the students with theory and practice of biological control, mass production techniques and field evaluation of various biological control agents like parasitoids, predators and various entomopathogenic microorganisms.

V. Theory

Unit I

History, principles and scope of biological control; important groups of parasitoids, predators and pathogens; principles of classical biological control- importation, augmentation and conservation. History of insect pathology, infection of insects by bacteria, fungi, viruses, protozoa, rickettsiae, spiroplasma and nematodes.

Unit II

Biology, adaptation, host seeking behaviour of predatory and parasitic groups of insects. Role of insect pathogenic nematodes, viruses, bacteria, fungi, protozoa, etc., their mode of action. Biological control of weeds using insects. Epizootiology, symptomatology and etiology of diseases caused by the above and the factors controlling these. Defense mechanisms in insects against pathogens.

Unit III

Mass production of quality bio-control agents- techniques, formulations, economics, field release/ application and evaluation. Development of insectaries, their maintenance.

Unit IV

Successful biological control projects, analysis, trends and future possibilities of biological control. Importation of natural enemies- Quarantine regulations, biotechnology in biological control. Semiochemicals in biological control.

VI. Practical

- Identification of common natural enemies of crop pests (parasitoids, predators, microbes) and weed killers;
- Visits to bio-control laboratories to learn rearing and mass production of egg, egg-larval, larval, larval-pupal and pupal parasitoids, common predators, microbes and their laboratory hosts, phytophagous natural enemies of weeds;
- Field collection of parasitoids and predators. Hands-on training in culturing, identification of common insect pathogens. Quality control and registration standards for biocontrol agents.

VII. Learning outcome

- Students are expected to have a good understanding of the role of natural enemies in managing pest populations below those causing economic damage
- Learn the techniques for mass production of quality bio-agents and their optimal use in IPM

VIII. Suggested Reading

Burges HD and Hussey NW. (Eds). 1971. *Microbial Control of Insects and Mites*. Academic Press, London.

De Bach P. 1964. *Biological Control of Insect Pests and Weeds*. Chapman and Hall, New York.

Dhaliwal GS and Arora R. 2001. *Integrated Pest Management: Concepts and Approaches*. Kalyani Publishers, New Delhi.

Gerson H and Smiley RL. 1990. *Acarine Biocontrol Agents – An Illustrated Key and Manual*. Chapman and Hall, New York.

Huffaker CB and Messenger PS. 1976. *Theory and Practices of Biological Control*. Academic Press, London.

Ignacimuthu SS and Jayaraj S. 2003. *Biological Control of Insect Pests*. Phoenix Publ., New Delhi.

Saxena AB. 2003. *Biological Control of Insect Pests*. Anmol Publ., New Delhi.

Van Driesche and Bellows TS. Jr. 1996. *Biological Control*. Chapman and Hall, New York.

I. Course Title : Toxicology of Insecticides

II. Course Code : ENT 506

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To orient the students with structure and mode of action of important insecticides belonging to different groups, development of resistance to insecticides by insects, environmental pollution caused by toxic insecticides and their toxicological aspects.

V. Theory

Unit I

Definition and scope of insecticide toxicology; history of chemical control; pesticide use and pesticide industry in India.

Unit II

Classification of insecticides and acaricides based on mode of entry, mode of action and chemical nature; categorization of insecticides on the basis of toxicity – criteria for bees, beneficial insects and other insects in general; structure and mode of action of organochlorines, organophosphates, carbamates, pyrethroids, tertiary amines, neonicotinoids, oxadiazines, phenyl pyrozoles, insect growth regulators, microbials, botanicals, new promising compounds/ new insecticide molecules; nanopesticides; drawbacks of insecticide abuse.

Unit III

Principles of toxicology; evaluation of insecticide toxicity; joint action of insecticides-synergism, potentiation and antagonism; factors affecting toxicity of insecticides; insecticide compatibility, selectivity and phytotoxicity. bioassay definition, objectives, criteria, factors, problems and solutions.

Unit IV

Insecticide metabolism; insect-pest resistance to insecticides; mechanisms and types of resistance; insecticide resistance management and pest resurgence.

Unit V

Insecticide residues, their significance and environmental implications; procedures of insecticide residue analysis. Insecticide Act, registration procedures, label claim, and quality control of insecticides; safe use of insecticides; diagnosis and treatment of insecticide poisoning.

VI. Practical

- Insecticide formulations and mixtures;
- Laboratory and field evaluation of bio-efficacy of insecticides;
- Bioassay techniques;
- Probit analysis;
- Evaluation of insecticide toxicity;
- Toxicity to beneficial insects;
- Pesticide appliances;
- Working out doses and concentrations of pesticides;
- Procedures of residue analysis.

VII. Learning outcome

- Students are expected understand the concept of toxicity, bio-efficacy, insecticide formulations, modes of action of insecticides, estimation of insecticide residues and have significant know-how about the functioning of various types of spray equipments.

VIII. Suggested Reading

Chattopadhyay SB. 1985. *Principles and Procedures of Plant Protection*. Oxford and IBH, New Delhi.

Dodia DA, Petel IS and Petal GM. 2008. *Botanical Pesticides for Pest Management*. Scientific Publisher (India), Jodhpur.
Dovener RA, Mueninghoff JC and Volgar GC. 2002. Pesticides formulation and delivery systems: meeting the challenges of the current crop protection industry. ASTM, USA
Gupta HCL.1999. *Insecticides: Toxicology and Uses*. Agrotech Publ., Udaipur.
Ishaaya I and Degheele (Eds.). 1998. *Insecticides with Novel Modes of Action*. Narosa Publ. House, New Delhi.
Ishaaya I and Degheele D. 1998. *Insecticides with Novel Modes of Action: Mechanism and Application*. Norosa Publishing House, New Delhi.
Krieger RI. 2001. *Handbook of Pesticide Toxicology*. Vol-II. Academic Press. Orlando Florida.
Mathews GA. 2002. *Pesticide Application Methods*. 4th Ed. Intercept. UK.
Matsumura F. 1985. *Toxicology of Insecticides*. Plenum Press, New York.
Otto D and Weber B. 1991. *Insecticides: Mechanism of Action and Resistance*. Intercept Ltd., UK.
Pedigo LP and Marlin ER. 2009. *Entomology and Pest Management*, 6th Edition, Pearson Education Inc., Upper Saddle River, New Jersey 07458, U.S.A.
Perry AS, Yamamoto I, Ishaaya I and Perry R. 1998. *Insecticides in Agriculture and Environment*. Narosa Publ. House, New Delhi.
Prakash A and Rao J. 1997. *Botanical Pesticides in Agriculture*. Lewis Publication, New York.
Roy NK. 2006. *Chemistry of Pesticides*. Asia Printograph Shahdara Delhi.

I. Course Title : Host Plant Resistance
II. Course Code : 507
III. Credit Hours : 2 (1+1)

IV. Aim of the course

To orient the students with host plant resistance.

V. Theory

Unit I

History and importance of resistance; principles, classification, components, types and mechanisms of resistance.

Unit II

Insect-host plant relationships; theories and basis of host plant selection in phytophagous insects.

Unit III

Chemical ecology, tritrophic relations, volatiles and secondary plant substances; basis of resistance. Induced resistance – acquired and induced systemic resistance.

Unit IV

Factors affecting plant resistance including biotypes and measures to combat them.

Unit V

Screening techniques; breeding for insect resistance in crop plants; exploitation of wild plant species; gene transfer, successful examples of resistant crop varieties in India and world.

Unit VI

Role of biotechnology in plant resistance to insects.

VI. Practical

- Screening techniques for measuring resistance;

- Measurement of plant characters and working out their correlations with plant resistance;
- Testing of resistance in important crops;
- Bioassay of plant extracts of susceptible/ resistant varieties;
- Demonstration of antibiosis, tolerance and antixenosis.

VII. Learning outcome

- Students are expected to acquire a thorough knowledge of the types and basis of mechanisms involved in host plant resistance, screening techniques to measure resistance and insect resistance breeding.

VIII. Suggested Reading

Dhaliwal GS and Singh R. (Eds). 2004. *Host Plant Resistance to Insects -Concepts and Applications*. Panima Publ., New Delhi.

Maxwell FG and Jennings PR. (Eds). 1980. *Breeding Plants Resistant to Insects*. John Wiley and Sons, New York.

Painter RH. 1951. *Insect Resistance in Crop Plants*. MacMillan, London.

Panda N and Khush GS. 1995. *Plant Resistance to Insects*. CABI, London.

Smith CM. 2005. *Plant Resistance to Arthropods – Molecular and Conventional Approaches*. Springer, Berlin.

I. Course Title : Concepts of Integrated Pest Management

II. Course Code : ENT 508

III. Credit Hours : 2 (2+0)

IV. Aim of the course

To familiarize the students with principles of insect pest management, including concept and philosophy of IPM. Train students in computation of ETL and implementing IPM programmes.

V. Theory

Unit I

History, origin, definition and evolution of various terminologies. Importance of resistance, principles, classification, components, types and mechanisms of resistance. National and international level crop protection organizations; insecticide regulatory bodies; synthetic insecticide, bio-pesticide and pheromone registration procedures; label claim of pesticides – the pros and cons.

Unit II

Concept and philosophy, ecological principles, economic threshold concept and economic consideration. Insect-host plant relationships; theories and basis of host plant selection in phytophagous insects.

Unit III

Tools of pest management and their integration- legislative, quarantine regulations, cultural, physical and mechanical methods; semiochemicals, biotechnological and bio-rational approaches in IPM. Pest survey and surveillance, forecasting, types of surveys including remote sensing methods, factors affecting surveys; political, social and legal implications of IPM; pest risk analysis; pesticide risk analysis; cost-benefit ratios and partial budgeting; case studies of successful IPM programmes. ITK-s in IPM, area-wide IPM and IPM for organic farming; components of ecological engineering with successful examples.

Unit IV

Characterization of agro-ecosystems; sampling methods and factors affecting sampling; population estimation methods; crop loss assessment direct losses, indirect losses, potential losses, avoidable losses, unavoidable losses; global and Indian scenario of crop losses. Computation of EIL and ETL; crop modeling; designing and implementing IPM system. Screening techniques; breeding for insect resistance in crop plants; exploitation of wild plant species; gene transfer, successful examples of resistant crop varieties in India and world.

VI. Learning outcome

- Students are expected to have significant knowledge of IPM concepts, estimation of losses due to insect pests, computation of ETL, EIL and should be able take management decisions.

VII. Suggested Reading

Dhaliwal GS and Arora R. 2003. *Integrated Pest Management – Concepts and Approaches*. Kalyani Publishers, New Delhi.

Horowitz AR and Ishaaya I. 2004. *Insect Pest Management: Field and Protected Crops*. Springer, New Delhi.

Ignacimuthu SS and Jayaraj S. 2007. *Biotechnology and Insect Pest Management*. Elite Publ., New Delhi.

Norris RF, Caswell-Chen EP and Kogan M. 2002. *Concepts in Integrated Pest Management*. Prentice Hall, New Delhi.

Pedigo RL. 2002. *Entomology and Pest Management*. 4th Ed. Prentice Hall, New Delhi.

Subramanyam B and Hagstrum DW. 1995. *Integrated Management of Insects in Stored Products*. Marcel Dekker, New York.

I. Course Title : Pests of Field Crops

II. Course Code : ENT 509

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To familiarize the students about nature of damage and seasonal incidence of pestiferous insects that cause loss to major field crops and their effective management by different methods.

V. Theory

Systematic position, identification, distribution, host-range, bionomics, nature and extent of damage, seasonal abundance and management of insect and mite pests and vectors. Insect pest scenario in relation to climate change.

Unit I

Polyphagous pests: grasshoppers, locusts, termites, white grubs, hairy caterpillars, and non-insect pests (mites, birds, rodents, snails, slugs, etc.). Insect pests of cereals and millets and their management.

Unit II

Insect pests of pulses, tobacco, oilseeds and their management.

Unit III

Insect pests of fibre crops, forage crops, sugarcane and their management.

VI. Practical

- Field visits, collection and identification of important pests and their natural enemies;
- Detection and estimation of infestation and losses in different crops;
- Study of life history of important insect pests.

VII. Learning outcome

- Students are expected to acquire knowledge of insect pests of field crops, their nature of damage, life history traits and effective management.

VIII. Suggested Reading

David, BV and Ramamurthy, VV. 2001. *Elements of Economic Entomology*. Popular Book Depot, Chennai.

Dhaliwal GS, Singh R and Chhillar BS. 2006. *Essentials of Agricultural Entomology*. Kalyani Publishers, New Delhi.

Dunston AP. 2007. *The Insects: Beneficial and Harmful Aspects*. Kalyani Publishers, New Delhi

Evans JW. 2005. *Insect Pests and their Control*. Asiatic Publ., New Delhi.

Nair MRGK. 1986. *Insect and Mites of Crops in India.* ICAR, New Delhi.

Prakash I and Mathur RP. 1987. *Management of Rodent Pests.* ICAR, New Delhi.

Saxena RC and Srivastava RC. 2007. *Entomology at a Glance.* Agrotech Publ. Academy, Udaipur.

I. Course Title : Pests of Horticultural and Plantation Crops

II. Course Code : ENT 510

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart knowledge on major pests of horticultural and plantation crops regarding the extent and nature of loss, seasonal history, their integrated management.

V. Theory

Systematic position, identification, distribution, host range, bionomics and seasonal abundance, nature and extent of damage and management of insect pests of various crops.

Unit I

Fruit Crops- mango, guava, banana, jack, papaya, pomegranate, litchi, grapes, *ber*, fig, citrus, *aonla*, pineapple, apple, peach and other temperate fruits.

Unit II

Vegetable crops- tomato, potato, radish, carrot, beetroot, cole crops, French beans, chow-chow, brinjal, okra, all gourds, drumstick, leafy vegetables, etc.

Unit III

Plantation crop- coffee, tea, rubber, coconut, arecanut, cashew, cocoa, etc.; Spices and Condiments- pepper, cardamom, clove, nutmeg, chillies, turmeric, ginger, beetlevine, etc.

Unit IV

Ornamental, medicinal and aromatic plants and pests in polyhouses/ protected cultivation.

VI. Practical

- Collection and identification of important pests and their natural enemies on different crops;
- Study of life history of important insect pests and non-insect pests.

VII. Learning outcome

- Students are expected to acquire knowledge of insect pests of horticultural, medicinal and plantation crops, their nature of damage, life history traits and effective management.

VIII. Suggested Reading

Atwal AS and Dhaliwal GS. 2002. *Agricultural Pests of South Asia and theirManagement*. Kalyani Publishers, New Delhi.

Butani DK and Jotwani MG. 1984. *Insects and Vegetables*. Periodical Expert Book Agency, New Delhi.

Dhaliwal GS, Singh R and Chhillar BS. 2006. *Essential of Agricultural Entomology*. Kalyani Publishers, New Delhi.

Srivastava RP. 1997. *Mango Insect Pest Management*. International Book Distr., Dehra Dun.

Verma LR, Verma AK and Goutham DC. 2004. *Pest Management in Horticulture Crops: Principles and Practices*. Asiatech Publ., New Delhi.

I. Course Title : Post Harvest Entomology

II. Course Code : ENT 511

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To focus on requirement and importance of grain and grain storage, to understand the role of stored grain pests and to acquaint with various stored grain pest management techniques for avoiding losses in storage.

V. Theory

Unit I

Introduction, history of storage entomology, concepts of storage entomology and significance of insect pests. Post-harvest losses *in toto vis-à-vis* total production of food grains in India. Scientific and socio-economic factors responsible for grain losses. Concept of seed vault.

Unit II

Important pests namely insects, mites, rodents, birds and microorganisms associated with stored grain and field conditions including agricultural products; traditional storage structures; association of stored grain insects with fungi and mites, their systematic position, identification, distribution, host range, biology, nature and extent of damage, role of field and cross infestations and natural enemies, type of losses in stored grains and their effect on quality including biochemical changes.

Unit III

Ecology of insect pests of stored commodities/ grains with special emphasis on role of moisture, temperature and humidity in safe storage of food grains and commodities. Stored grain deterioration process, physical and biochemical changes and consequences. Grain storage- types of storage structures i.e., traditional, improved and modern storage structures in current usage. Ideal seeds and commodities' storage conditions.

Unit IV

Important rodent pests associated with stored grains and their non-chemical and chemical control including fumigation of rat burrows. Role of bird pests and their management. Control of infestation by insect pests, mites and microorganisms. Preventive measures- Hygiene/ sanitation, disinfestations of stores/ receptacles, legal methods. Curative measures- Non-chemical control measures- ecological, mechanical, physical, cultural, biological and engineering. Chemical control- prophylactic and curative- Characteristics of pesticides, their use and precautions in their handling with special emphasis on fumigants. Insecticide resistance in stored product pests and its management; recent advances (MAS, PPP, HS) in storage pest management; integrated approaches to stored grain pest management.

VI. Practical

- Collection, identification and familiarization with the stored grains/ seed insect pests and nature of damage caused by them;
- Detection of hidden insect infestation in stored food grains;
- Estimation of uric acid content in infested produce; estimation of losses in stored food grains;
- Determination of moisture content in stored food grains;
- Familiarization of storage structures, demonstration of preventive and curative measures including fumigation techniques;
- Treatment of packing materials and their effect on seed quality;
- Field visits to save grain campaign, central warehouse and FCI warehouses and institutions engaged in research or practice of grain storage like CFTRI, Mysore; IGSMRI, Hapur, etc. (only where logistically feasible).

VII. Learning outcome

- Students are expected to acquire knowledge of pestiferous insects, mites, rats and birds affecting stored produce, their nature of damage, life history traits and effective management.
- Detection of insect infestation and familiarization with different storage structures.
- Learning preventive and curative measures to manage infestation in storage houses.

VIII. Suggesting Reading

Hall DW. 1970. *Handling and Storage of Food Grains in Tropical and Subtropical Areas.* FAO. Agricultural Development Paper No. 90 and FAO, Plant Production and Protection Series No. 19, FAO, Rome.

Jayas DV, White NDG and Muir WE. 1995. *Stored Grain Ecosystem.* Marcel Dekker, New York.

Khader V. 2004. *Textbook on Food Storage and Preservation.* Kalyani Publishers, New Delhi.

Khare BP. 1994. *Stored Grain Pests and Their Management.* Kalyani Publishers, New Delhi.

Subramanyam B and Hagstrum DW. 1995. *Interrelated Management of Insects in Stored Products.* Marcel Dekker, New York.

I. Course Title : Insect Vectors of Plant Pathogens

II. Course Code : ENT 512

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To teach the students about the different groups of insects that act as vectors of plant pathogens, vector-plant pathogen interaction, and management of vectors for controlling diseases.

V. Theory

Unit I

History of developments in the area of insects as vectors of plant pathogens. Important insect vectors and their characteristics; mouth parts and feeding processes of important insect vectors. Efficiency of transmission.

Unit II

Transmission of plant viruses and fungal pathogens. Relation between viruses and their vectors.

Unit III

Transmission of plant viruses by aphids, whiteflies, mealy bugs and thrips.

Unit IV

Transmission of mycoplasma and bacteria by leaf hoppers and plant hoppers.

Unit V

Transmission of plant viruses by psyllids, beetles and mites. Epidemiology and management of insect transmitted diseases through vector management.

VI. Practical

- Identification of common vectors of plant pathogens- aphids, leafhoppers, whiteflies, thrips, beetles, nematodes;
- Culturing and handling of vectors; demonstration of virus transmission through vectors- aphids, leafhoppers and whiteflies;
- Vector rearing and maintenance;
- Estimating vector transmission efficiency, studying vector-virus host interaction.

VII. Learning outcome

- Students are expected to be well versed with insect vectors of plant pathogens, acquire knowledge on disease transmission and vector management techniques.

VIII. Suggested Reading

Basu AN. 1995. *Bemisia tabaci* (Gennadius) – *Crop Pest and Principal Whitefly Vector of Plant Viruses*. Oxford and IBH, New Delhi.

Harris KF and Maramarosh K. (Eds.). 1980. *Vectors of Plant Pathogens*. Academic Press, London.

Maramorosch K and Harris KF. (Eds.). 1979. *Leafhopper Vectors and Plant Disease Agents*. Academic Press, London.

Youdeovei A and Service MW. 1983. *Pest and Vector Management in the Tropics*. English Language Books Series, Longman, London.

I. Course Title : Principles of Acarology

II. Course Code : ENT 513

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To acquaint the students with external morphology of different groups of mites, train in identification of commonly occurring families of plant associated mites, provide information about important mite pests of crops and their management.

V. Theory

Unit I

History of Acarology; importance of mites as a group; habitat, collection and preservation of mites. Soil arthropods and their classification, habitats and their identification.

Unit II

Introduction to morphology and biology of mites and ticks. Broad classification-major orders and important families of Acari including diagnostic characteristics. Estimation of populations; sampling and extraction methods for soil arthropods.

Unit III

Economic importance, seasonal occurrence, nature of damage, host range of mite pests of different crops, mite pests in polyhouses, mite pests of stored products and honeybees. Management of mites using acaricides, phytoseiid predators, fungal pathogens, etc. Culturing of phytophagous, parasitic and predatory mites. Mode of action of acaricides, resistance of mites and ticks to acaricides, its management.

VI. Practical

- Collection of mites from plants, soil and animals;
- Extraction of mites from soil, plants and stored products;
- Preparation of mounting media and slide mounts;
- External morphology of mites;
- Identification of mites up to family level using keys;
- Studying different rearing techniques for mites.

VII. Learning outcome

- Students are expected to identify mites up to family level.
- Acquire knowledge of mite pests of cultivated crops, their nature of damage, life history traits and effective management.

VIII. Suggested Reading

Anderson JM and Ingram JSI. 1993. *Tropical Soil Biology and Fertility: A Handbook of Methods.* CABI, London.

Chhillar BS, Gulati R and Bhatnagar P. 2007. *Agricultural Acarology*. Daya Publ. House, New Delhi.

Dindal DL. 1990. *Soil Biology Guide*. A Wiley-InterScience Publ., John Wiley and Sons, New York.

Gerson U and Smiley RL. 1990. *Acarine Biocontrol Agents – An Illustrated Key and Manual*. Chapman and Hall, NewYork.

Gupta SK. 1985. *Handbook of Plant Mites of India.* Zoological Survey of India, Calcutta.

Gwilyn O and Evans GO. 1998. *Principles of Acarology*. CABI, London.

Jeppson LR, Keifer HH and Baker EW. 1975. *Mites Injurious to Economic Plants*. University of California Press, Berkeley.

Krantz GW. 1970. *A Manual of Acarology*. Oregon State Univ. Book Stores, Corvallis, Oregon.

Pankhurst C, Dube B and Gupta, V. 1997. *Biological Indicators of Soil Health.* CSIRO, Australia.

Qiang Zhiang Z. 2003. *Mites of Green Houses- Identification, Biology and Control*. CABI, London.

Sadana GL. 1997. *False Spider Mites Infesting Crops in India.* Kalyani Publishers House, New Delhi.

Walter DE and Proctor HC. 1999. *Mites- Ecology, Evolution and Behaviou*r. CABI, London.

Veeresh GK and Rajagopal D. 1988. *Applied Soil Biology and Ecology*. Oxford and IBH Publ., New Delhi.

I. Course Title : Vertebrate Pest Management

II. Course Code : ENT 514

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To impart knowledge on vertebrate pests like birds, rodents, mammals and others of different crops, their biology, damage they cause and management strategies.

V. Theory

Unit I

Introduction to vertebrate pests of different crops; biology of vertebrate pests such as rodents, birds and other mammals.

Unit II

Bio-ecology of birds of agricultural importance, patterns of pest damage and assessment, roosting and nesting systems in birds; management of pestiferous birds; conservation of predatory birds.

Unit III

Bio-ecology of rodents of agricultural importance, patterns of pest damage and assessment, burrowing pattern and habitat of rodents; management of pestiferous rodents.

Unit IV

Bio-ecology of higher vertebrates of agricultural importance, patterns of damage and assessment, their habitat; management of pestiferous vertebrates.

Unit V

Management strategies- physical (trapping, acoustics and visual), chemical (poisons, repellents, fumigants and anticoagulants), biological (predators, parasites), cropping practices, alteration of habitats, diversion baiting and other eco-friendly methods – Operational practices- baiting, equipments and educative programmes.

VI. Practical

- Identification of important rodents, birds and other vertebrate pests of agriculture, food preference and hoarding;
- Social behaviour, damage assessment, field survey, population estimation, management strategies: preventive and curative methods.

VII. Learning outcome

- Students are expected to be well versed with vertebrate pest diversity, their nature of damage, life history traits, behaviour and effective management.

VIII. Suggested Reading

Ali S. 1965. *The Book of Indian Birds*. The Bombay Natural History Society, Bombay.
Fitzwater WD and Prakash I. 1989. *Handbook of Vertebrate Pest Control*. ICAR, New Delhi.
Prakash I and Ghosh PK. 1997. *Rodents in Indian Agriculture*. Vol. I. State of Art Scientific Publ., Jodhpur.
Prakash I and Ghosh RP. 1987. *Management of Rodent Pests*. ICAR, New Delhi.
Prater SH. 1971. *The Book of Indian Animals*. The Bombay Natural History Society, Bombay.
Rahman A. 2020. *Protective and Productive Entomology* Narendra Publishing House, New Delhi

I. Course Title : Techniques in Plant Protection

II. Course Code : ENT 515

III. Credit Hours : 1 (0+1)

IV. Aim of the course

To acquaint the students with appropriate use of plant protection equipments and techniques related to microscopy, computation, pest forecasting, etc.

V. Practical

- Pest control equipments, principles, operation, maintenance, selection, and

application of pesticides;
- Release of bio-control agents;
- Seed dressing, soaking, root-dip treatment, dusting, spraying, and pesticide application through irrigation water;
- Application of drones in plant protection;
- Soil sterilization, solarization, deep ploughing, flooding, techniques to check the spread of pests through seed, bulbs, corms, cuttings and cut flowers;
- Uses of light, transmission and scanning electron microscopy;
- Protein isolation from the pest and host plant and its quantification using spectrophotometer and molecular weight determination using SDS/ PAGE;
- Use of tissue culture techniques in plant protection;
- Computer application for predicting/ forecasting pest attack and identification.

VI. Learning outcome

- Students are expected to have a good knowledge of different plant protection equipments and techniques related to pest forecasting.

VII. Suggested Reading

Alford DV. 1999. *A Textbook of Agricultural Entomology*. Blackwell Science, London.
Crampton JM and Eggleston P. 1992. *Insect Molecular Science*. Academic Press, London.

I. Course Title : Apiculture

II. Course Code : ENT 516

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart knowledge about the honey bees, and their behaviour and activities; bee husbandry, bee multiplication, bee enemies and diseases and their management; hive products, apitherapy; and managed bee pollination of crops

V. Theory

Unit I

Historical development of apiculture at global level and in India; Classification of bees; global distribution of genus *Apis* and races; Morphology and anatomy of honey bee; Honey bee biology, ecology, adaptations; Honey bee behaviour – nest founding, comb construction, brood care, defense, other in-house and foraging activities; Bee pheromones; Honey bee communication.

Unit II

Commercial beekeeping as an enterprise; Design and use of bee hives; Apicultural equipment; Seasonal bee husbandry; Honey bee nutrition and artificial diets; Absconding, swarming, drifting – causes and management; Curbing drone rearing; Laying worker menace – causes, signs and management.

Unit III

Bee genetics; Principles and procedures of bee breeding; Screening of honey bee colonies; Techniques in mass queen bee rearing; Mating nuclei and their establishment; Selective mating; Queen bee management; Bee packages.

Unit IV

Ectoparasitic and endoparasitic bee mites – biology, ecology, nature and symptoms of damage, management tactics; Wax moths, wasps and ants – biology, ecology, nature and symptoms of damage, management tactics; Predatory birds, their damage potential and management tactics; Pesticide poisoning to honey bees, signs and protection; Protocols in evaluation of pesticide toxicity to honey bees.

Unit V

Honey – composition, properties, crystallization, post-harvest handling and processing; Honey quality standards and assessment; Apicultural diversification – potential and profitability; Production/ collection of bee pollen, propolis, royal jelly, bee venom and bees wax and their post-harvest handling; Apitherapy; Value addition of hive products; Development of apiculture project.

Unit VI

Non-*Apis* pollinators, their augmentation and conservation; Role of bee pollinators in augmenting crop productivity; Managed bee pollination of crops.

VI. Practical

- Morphological characteristics of honey bee;
- Mouthparts; digestive, respiratory and reproductive adaptations in different castes of honey bees;
- Recording of colony performance;
- Seasonal bee husbandry practices;
- Swarming, queenlessness, swarming, laying workers menaces, etc. and their remedies;
- Innovative techniques in mass queen bee rearing; selection and breeding of honey bees;
- Instrumental insemination; formulation of artificial diets and their feeding;
- Production technologies for various hive products;
- Bee enemies and diseases and their management;
- Recording pollination efficiency;
- Application of various models for determining pollination requirement of crop;
- Developing a beekeeping project.

VII. Learning outcome

- Students are expected to have a comprehensive knowledge of bee biology, physiology and bee keeping/ apiculture.
- With practical training it is expected that students develop entrepreneurial skills for apiculture.

VIII. Suggested Reading

Abrol DP and Sharma D. 2009. *Honey Bee Mites and Their Management*. Kalyani Publishers, New Delhi, India.

Abrol DP. 2009. *Honey bee Diseases and Their Management*. Kalyani Publishers, New Delhi, India.

Abrol DP. 2010. *Beekeeping: A Compressive Guide to Bees and Beekeeping*. Scientific Publishers, India.

Abrol DP. 2010. *Bees and Beekeeping in India*. Kalyani Publishers, New Delhi, India.

Abrol DP. 2012. *Pollination Biology: Biodiversity Conservation and Agricultural Production*. Springer.

Atwal AS. 2001. *World of Honey Bees*. Kalyani Publishers, New Delhi- Ludhiana, India.

Atwal AS. 2000. *Essentials of Beekeeping and Pollination*. Kalyani Publishers, New Delhi-Ludhiana, India.

Bailey L and Ball BV. 1991. *Honey Bee Pathology*. Academic Press, London.
Crane Eva and Walker Penelope. 1983. *The Impact of Pest Management on Bees and Pollination*. Tropical Development and Research and Institute, London.
Free JB. 1987. *Pheromones of Social Bees*. Chapman and Hall, London.
Gatoria GS, Gupta JK, Thakur RK and Singh Jaspal. 2011. *Mass Multiplication of Honey Bee Colonies*. ICAR, New Delhi, India.
Grahm Joe M. 1992. *Hive and the Honey Bee*. Dadant & Sons, Hamilton, Illinois, USA.
Grout RA. 1975. *Hive and the Honey Bee*. Dadant & Sons, Hamilton, Illinois, USA.
Holm E. 1995. *Queen Rearing Genetics and Breeding of Honey Bees*. Gedved, Denmark.
Laidlaw HH Jr and Eckert JE. 1962. *Queen Rearing*. Berkeley, University of California Press.
Laidlaw HH. 1979. *Contemporary Queen Rearing*. Dadant & Sons, Hamilton, Illinois, USA.
Mishra RC. 2002. *Perspectives in Indian Apiculture*. Agro-Botanica, Jodhpur, India.
Mishra RC. 1995. *Honey Bees and their Management in India*. I.C.A.R., New Delhi, India.
Morse AA. 1978. *Honey Bee Pests, Predators and Diseases*. Cornell University Press, Ithaca and London.
Rahman, A. 2017. *Apiculture in India*, ICAR, New Delhi
Ribbands CR. 1953. *The Behaviour and Social Life of Honey Bees*. Bee Research Association Ltd., London, UK.
Rinderer TE. 1986. *Bee Genetics and Breeding*. Academic Press, Orlando.
Sardar Singh. 1962. *Beekeeping in India*. I.C.A.R., New Delhi, India (Reprint: 1982).
Seeley TD. 1985. *Honey Bee Ecology*. Princeton University Press, 216 pp.
Snodgrass RE. 1925. *Anatomy and Physiology of the Honey Bee*. Mc Graw Hill Book Co., New York & London.
Snodgrass RE. 1956. *Anatomy of the Honey Bee*. Comstock Publishing Associates, Cornell Univ. Press, Ithaca, New York.

I. Course Title : Sericulture
II. Course Code : ENT 517
III. Credit Hours : 3 (2+1)

IV. Aim of the Course

To familiarize the students with entrepreneurial opportunities in entomology, sericulture in particular, and providing information on silk worm rearing, production and management.

V. Theory

Unit I

History of Sericulture, importance, organizations involved in sericulture activities, silkworm types, distribution, area and silk production.

Unit II

Mulberry species, ecological requirements, cultivation, improved varieties, propagation methods, sapling production, planting and pruning techniques; pest and diseases, management strategies; intercropping, water and weed management. Food plants of eri silkworm, castor cultivation, intercultural operations, nutrient and water management; method of harvest; host plants of Tasar, nursery and cultivation, selection of seed, soaking and heap making, pruning techniques. Food plants of Muga silkworm, Som and Soalu propagation methods; nursery techniques; intercultural operations and weed management.

Unit III

Silkworm origin – classification based on voltinism, moultinism, geographical distribution and genetic nature – pure races –multivoltine and bivoltine races – cross breeds – bivoltine hybrids –Races and hybrids of mulberry, eri, tasar and muga silkworm- Morphology and biology of silkworm, sex limited characters; anatomy of digestive and excretory systems of larva; structure and function of silk glands.

Unit IV

Rearing house, types, disinfection, room and bed disinfectants; egg incubation methods, Chawki rearing, feeding, cleaning and spacing; rearing of late age worms, feeding, cleaning, spacing and moulting care; mountages, cocoon harvesting and marketing; pests and diseases of silkworms and their management.

Unit V

Post cocoon technology, stifling, cocoon cooking, brushing, reeling, re-reeling, bleaching, degumming, dyeing, printing and weaving, different reeling machines; value addition in sericulture; economics of sericulture.

VI. Practical

- Morphology of mulberry plants;
- Identification of popular mulberry genotypes;
- Nursery bed and main field preparation;
- Planting methods;
- Identification of nutrient deficiency symptoms;
- Identification of weeds;
- Pruning and harvesting methods;
- Identification of pests and diseases of mulberry–*Terminalia arjuna, Terminalia tomentosa,* Som and Soalu- Nursery and pruning techniques – Intercultural operations;
- Morphology of silkworm – Identification of races – Dissection of mouth parts and silk glands – Disinfection techniques – rearing facilities – silkworm rearing – feeding, cleaning and spacing – Identification of pests and diseases of mulberry silkworm – hyperparasitoids and mass multiplication techniques – silkworm egg production technology –Tasar, Eri and muga silkworms – rearing methods–pests and diseases of non-mulberry silkworms – Visit to grainage, cocoon market and silk reeling centre – Economics of silkworm rearing.

VII. Learning outcome

- Students taking up sericulture are expected to have a thorough knowledge of silkworm morphology, races, biology, and all the practices of rearing for silk production.
- They should be well versed with the pests and diseases of silkworm and their management.
- With practical training it is expected that students develop entrepreneurial skills for sericulture or link up with industries to sell cocoons for silk production or guide farmers engaged in silk worm rearing/ sericulture.

VIII. Suggested Reading

Dandin SB and K Giridhar. 2014. Hand book of Sericulture Technologies. Central Silk Board, Bangalore, 423p.

Govindaiah G, VP, Sharma DD, Rajadurai S and Nishita V Naik. 2005. A text book on mulberry crop protection. Central Silk Board, Bangalore.450 p.

Jolly MS, Sen SK, Sonwalkar TN and Prasad GK. 1980. Non–mulberry Silks. FAO Agicultural Services Bulletin 29. Food and Agriculture Organization of the United Nations, Rome, 178 p.
Mahadevappa D, Halliyal VG, Shankar DG and Ravindra Bhandiwad. 2000. Mulberry Silk Reeling Technology. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi. 234 p.
Mohanty PK. 2003. Tropical wild cocoons of India. Daya Publications, Tri Nagar, New Delhi, 197 p.
Nataraju B, Sathyaprasad K, Manjunath D and Kumar A. 2005. Silkworm crop protection. CSB, Bangalore. 412 pp.
Rangaswami G, Narasimhanna MN, Kasiviswanathan K, Sastry CR and Jolly MS. 1976. Food Plants of non-mulberry silkworms. In: *Mulberry cultivation*. FAO Agricultural Services Bulletin. Vol.1, Chapter-13. Rome, Italy. 96 p.
Tribhuvan Singh and Saratchandra B. 2004. Principles and Techniques of silkworm seed production. Discovery publishing House, New Delhi, 360 pp.

IX. E-resources

www.silkwormgenomics.org; www.silkboard.com; ww.silkgermplasm.com; www.csrtimys.res.in

I. Course Title : Lac Culture

II. Course Code : ENT 518

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To familiarize the students with entrepreneurial opportunities in entomology with an emphasis on lac culture in particular. To provide information on lac insect rearing, production and management.

V. Theory

Unit I

History of lac production; importance, potential of lac production in India; organizations involved in lac production activities; strains of lac insects and lac crops – distribution, area and production of different strains of lac.

Unit II

Steps and operation of lac production; lac host plant species, ecological requirements, their cultivation; seasons of host plants, harvest time of host plants, rearing seasons; grouping of host trees, pruning methods, timing; lac host plant pests and diseases; management strategies.

Unit III

Basic morphology and taxonomy of lac insect, strains of lac insect and their characteristics; composition of lac; biology of lac insect, species diversity and distribution.

Unit IV

Introduction, lac insect-host plant interaction; selection of brood lac, local practices, improved alternatives, coupe system; propagation of lac insects: natural self inoculation, artificial inoculation; inoculation process and duration; removal of phunki, harvesting of lac, immature harvesting, mature harvesting and time of harvesting. Predators and parasitoids of lac insect, hyperparasites, diseases and their management.

Unit V

Lac production stages; factors affecting yield and quality of shellac. Pure stock of host plants (kusum, palas, ber, pigeonpea, semialata); alternative method; technology of brood preserving. Host-specific technologies – cultivation on specific host plants; integration of lac cultivation with agro-forestry and horticulture; socio-economic potential of lac; export-import of lac/ lac products; marketing of lac and its products. Lac processing and value addition; entrepreneurship development.

VI. Practical

- Lac host cultivation and lac production practices;
- Equipments for lac production;
- Conventional and advanced methods;
- Coupe system of lac production;
- Cultivation of suitable host plants;
- Pruning of host trees;
- Herbarium of host plants;
- Strains of lac insects;
- Brood lac selection and treatment for pest management;
- Slide preparation of adult and immature stages;
- Inoculation of host tree;
- Identification of natural enemies of lac insect and their management;
- Molecular characterization of lac insect where possible;
- Harvesting;
- Process of manufacture of seed lac, shell lac from stick lac;
- Grading of seed lac and shellac;
- Marketing of lac products and by products.

VII. Learning outcome

- The students are expected to have good knowledge of lac host trees and their maintenance for lac production.
- It is expected that they should perfect the most suitable techniques for lac producton with a good knowledge about diseases and natural enemies of the lac insect.
- With practical training it is expected that students are able to guide landless labourers, who bring stick lac as forest produce.

VIII. Suggested Reading

David BV and Ramamurthy VV. 2011. *Elements of Economic Entomology*, 6th Edition, Namrutha Publications, Chennai.

Sharma KK and Ramani S. 2010. *Recent advances in lac culture*. ICAR-IINRG, Ranchi.

I. Course Title : Molecular Approaches In Entomology

II. Course Code : ENT 519

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To acquaint students the latest techniques used in molecular biology.

V. Theory

Unit I

Introduction to molecular biology, techniques used in molecular biology.

Unit II

DNA recombinant technology, identification of genes/ nucleotide sequences for traits of interest, techniques of interest in plants and microbes.

Unit III

Genes of interest in entomological research- marker genes for sex identification, peptides and neuropeptides, JH esterase, St toxins and venoms, chitinase, Plant-derived enzyme inhibitors, protease inhibitors, trypsin inhibitors, á-amylase inhibitors, lectins, terepenes and terpenoids; genes of non-plant origin, *Bacillus thuringiensis* endotoxins, mode of action of cry genes, classification and properties, synthetic Bt toxin genes, Other toxin genes, genes derived from entomophagous viruses, transgenic plants for pest resistance.

Unit IV

Genetically engineered microbes and parasitoids in biological control-Genetic engineering in baculoviruses and fungal biocontrol agents for greater efficacy against insect pests. Effects of transgenic plants on pest biology and development, resistance management strategies in transgenic crops, molecular mechanism of insecticide resistance.

Unit V

Genetic-based methods for agricultural insect pest management-insect pest management through sterile insect technique and relase of insects carrying a dominant lethal gene. Methods and application of insect trangenesis, transgenics in silkworm and honeybees. Molecular tools for taxonomy and phylogeny of insect-pests, DNA-based diagnostics. Nano technology and its application.

VI. Practical

- Isolation of DNA/ RNA;
- Agarose gel electrophoresis of DNA, quantification of DNA by spectrophotometirc and agarose gel analysis, PCR amplification of mitochondrial cytochrome oxidase subunit I gene (cox1) and 16S rRNA gene, cloning of PCR amplicons in standard plasmid vectors for sequencing, confirmation of the insert, miniprep of recombinant plasmid DNA, BLAST analysis and multiple sequence alignment of the sequence with sequences already available in GenBank;
- Isolation of host plant proteins, SDS-PAGE of the isolated proteins.

VII. Learning outcome

- The students are expected to be well versed with the basic techniques used in molecular biology.

VIII. Suggested Reading

Bhattacharya TK, Kumar P and Sharma A. 2007. *Animal Biotechnology*. 1st Ed., Kalyani Publication, New Delhi.

Hagedon HH, Hilderbrand JG, Kidwell MG and Law JH. 1990. *Molecular Insect Science*. Plenum Press, New York.

Hoy MA. 2003. *Insect Molecular Genetics: An Introduction to Principles and Applications*. 2nd Ed. Academic Press, New York.

Oakeshott J and Whitten MA. 1994. *Molecular Approaches to Fundamental and Applied Entomology*. Springer Verlag.

Rechcigl JE and Rechcigl NA. 1998. *Biological and Biotechnological Control of Insect Pests*. Lewis Publ., North Carolina.

Roy U and Saxena V. 2007. *A Hand Book of Genetic Engineering*. 1st Ed., Kalyani Publishers, New Delhi.
Singh BD. 2008. *Biotechnology (Expanding Horizons)*. Kalyani Publishers, New Delhi.
Singh P. 2007. *Introductory to Biotechnology*. 2nd Ed. Kalyani Publishers, New Delhi.

I. Course Title : Plant Quarantine, Bio-safety and Bio-security
II. Course Code : ENT 520
III. Credit Hours : 2 (2+0)

IV. Aim of the course

To acquaint the learners about the principles and the role of Plant Quarantine in containment of pests and diseases, plant quarantine regulations and set-up. Also, to facilitate students to have agood understanding of the aspects of biosafety and biosecurity.

V. Theory

Unit I

Definition of pest, pesticides and transgenics as per Govt. notification; relative importance; quarantine – domestic and international. Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case histories of exotic pests/ diseases and their status.

Unit II

Plant protection organization in India. Acts related to registration of pesticides and transgenics. Insecticide regulatory bodies, synthetic insecticides, bio-pesticides and pheromone registration procdures. History of quarantine legislations, PQ Order 2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

Unit III

Identification of pest/ disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniques to detect pest/ pathogen infestations; VHT and other safer techniques of disinfestation/ salvaging of infected material.

Unit IV

WTO regulations; non-tariff barriers; pest risk analysis, good laboratory practices for pesticide laboratories; pesticide industry; sanitary and phytosanitary measures. Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/ disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity. Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, issues related to release of genetically modified crops.

VI. Learning outcome

- Students offering this course are expected to have a good knowledge of the rules and regulations of Plant Quarantine, WTO regulations, GAP, Sanitary and Phytosanitary measures.

VII. Suggested Reading

Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.

Rhower GG. 1991. Regulatory Plant Pest Management. In: *Handbook of Pest Management in Agriculture*. 2nd Ed. Vol. II. (Ed. David Pimental), CRC Press.
Shukla A and Veda OP. 2007. *Introduction to Plant Quarantine*. Samay Prakashan, New Delhi.

I. Course Title : Edible and Therapeutic Insects
II. Course Code : ENT 521
III. Credit Hours : 2 (1+1)

IV. Aim of the course

To create awareness and acquaint students about the contribution that insects make to ecosystems, diets, food security and livelihoods in developed and developing countries.

V. Theory

Unit I
Edible and therapeutic insects: the concept, definition, and importance.

Unit II
History and origin of insects as food, feed and medication; important insect species and insect products consumed.

Unit III
Edible insect ecology, conservation and management of edible insect resources; environmental opportunities of insect rearing.

Unit IV
Nutritional composition and role of insects in food security.

Unit V
Insect farming: the concept, definitions, and rearing techniques.

Unit VI
Processing edible insects for food and feed.

Unit VII
Food safety and preservation, edible insects for livelihood security.

VI. Practical

- Survey and identification of edible and therapeutic insect species;
- Collection and preservation of edible and therapeutic insect specimens;
- Rearing techniques of edible insect species;
- Harvesting techniques of edible insects from natural environment;
- Analysis of proximate elemental composition, antioxidant and anti-nutritional properties and microbial aspects of preservation.

VII. Learning outcome

- Students are expected to be aware of insects for edible and therapeutic use; their nutritional composition.
- Should know the techniques of farming and processing insects for human and animal consumption.

VIII. Suggested Reading

Halloran A, Flore R, Vantomme P and Roos N 2018. Edible insects in sustainable food systems.
Van Huis A, Itterbeeck JK, Klunder H, Mertens E, Halloran A, Muir G and Vantomme. 2013. Edible insects: future prospects for food and feed security. Food and Agricultural Organization of the United Nations, Rome.

I. Course Title : Medical and Veterinary Entomology

II. Course Code : ENT 522

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To study the major insect, mite, and tick vectors of disease to man and animals. Students will learn to identify and understand the life cycles, morphology, and behavior of mosquitoes, ticks, mites, lice, fleas, and other disease vectors.

V. Theory

Unit I

Introduction to medical, veterinary and forensic entomology; Classification of Arthropod-borne diseases; Hematophagy, disease transmission and epidemiology; flies (Diptera) of medical and veterinary Importance; moth flies: Leishmaniasis and Bartonellosis; biting midges (Ceratapogonidae).

Unit II

Mosquito taxonomy, biology, and behavior; mosquito viruses: EEE, VEE, SLE, yellow fever,mosquito surveillance; malaria; horse flies, deer flies: EIA, anaplasmosis; muscid flies; Myiasis (Muscoidea); myiasis and louse flies; black flies of medical and veterinary Importance; filariasis: mansonellosis, onchocerciasis.

Unit III

Lice of medical and veterinary importance; rickettsial diseases: epidemic typhus, etc.; mites: rickettsial pox; mites and acariasis: mange, scabies, chiggers; spiders and scorpions; fleas (Siphonaptera) of medical and veterinary importance; plague and murine typhus.

Unit IV

Ticks of medical and veterinary importance; lyme disease, rocky mountain spotted fever, tularemia; true bugs (Hemiptera): kissing bugs and bedbugs; chagas disease; tsetse flies; Lepidoptera and Hymenoptera of medical and veterinary importance.

VI. Practical

- Identification of arthropod Classes, Orders and Families of medical and veterinary importance;
- Collection, segregation, curing insect and arachnid specimens, their preservation;
- Management of insect and mite pests of medical and veterinary importance;
- Study of some practical aspects in forensic entomology.

VII. Learning outcome

- Students are expected to identify the arthropods of medical and veterinary importance; identify the diseases transmitted by these arthropod vectors and suggest management options.

VIII. Suggested Reading

David BV and Ramamurthy VV. 2011. *Elements of Economic Entomology*, 6th Edition, Namrutha Publications, Chennai.

Gullan PJ and Cranston PS. 2010. *The Insects: An Outline of Entomology*. 4th Edition, Wiley-Blackwell, West Sussex, UK & New Jersey, US.

Mullen G and Durden L. 2018. *Medical and Veterinary Entomology*, 3rd Edition, Academic Press.

I. Course Title : Forest Entomology

II. Course Code : ENT 523

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To promote a more global theoretical understanding of pest population dynamics and the causes of forest insect outbreaks: covering pests of both natural forests and plantations, the diversity of tropical forest insects, their ecological functions, the concept of pests and the incidence of pests in natural forests, plantations and stored timber.

V. Theory

Unit I

Introduction to forestry in the tropics, tropical forests: characteristics and types of tropical forests, management of tropical forests and the problems in their management; plantation forestry: beginnings, expansion and current status.

Unit II

History of tropical forest entomology, diversity of forest insects: structural and functional diversity – the feeding guilds, concept of pests, ecology of insects in forest environment, concept and functioning of ecosystem, role of insects in ecosystem processes of tropical forests: insects as primary consumers, secondary and tertiary consumers, as decomposers, as food, pollinators and other ecological interactions.

Unit III

Insect pests in natural forests, general pest incidence, pest outbreaks: Lepidoptera, Coleoptera, Hemiptera, and Hymenoptera; insect pests in plantations, nursery pests, sapling pests, pests of older plantations and their impact; insect pests of stored timber, categories of wood destroying insects and their damage: termites and beetles.

Unit IV

Population dynamics, characteristics of population growth, factors affection population growth, principles governing population dynamics, types and causes of forest insect outbreaks; general issues in forest entomology: enemies' hypothesis, resource concentration hypothesis, pest evolution hypothesis; pest problems in plantations of indigenous *vs* exotic species; pest problems in monocultures *vs* mixed plantations.

Unit V

Management of tropical forest insect pests, historical development and present status of tropical forest pest management, overview of pest management options: preventive measures, remedial measures; unique features of forest pest management; constraints to forest pest management in the tropics; guidelines for the practice of forest pest management in the tropics.

Unit VI

Insect pests in plantations: Location-specific case studies.

VI. Practical

- Collection, identification and preservation of important insect pest specimens of forest plants and some damage material;

- Detection of insect infestation and assessment of losses due to insect pests;
- Habitat management for vertebrate and insects pests;
- Fire control methods and devices;
- Familiarization with the meteorological and plant protection equipment, application of pesticides and bio-control agents in the management of insect pests in nurseries and plantations.

VII. Learning outcome

- Students are expected to acquire knowledge of insect pests of forest nurseries, forests and plantations, their nature of damage, life history traits and effective management.
- Likewise, students are expected to have a thorough knowledge of pestiferous insects of stored timber, hide and other forest produce.

VIII. Suggested Reading

Jha LK and Sen Sarna PK. 1994. *Forest Entomology*. Ashish Publishing House, Delhi.

Nair KSS. 2007. *Tropical Forest Insect Pests: Ecology, Impact, and Management*, Cambridge University Press, Edinburgh/ New York.

Stebbings EP. 1977. *Indian Forest Insects*. JK Jain Brothers.

Course Title with Credit Load
Ph.D. in Plant Protection-Entomology

Course Code	Course Title	Credit Hours
ENT 601**	Insect Phylogeny and Systematics	3 (1+2)
ENT 602**	Insect Physiology and Nutrition	3 (2+1)
ENT 603**	Insect Ecology and Diversity	3 (2+1)
ENT 604	Insect Behaviour	2 (1+1)
ENT 605**	Bio-inputs for Pest Management	3 (2+1)
ENT 606**	Insect Toxicology and Residues	3 (2+1)
ENT 607	Plant Resistance to Insects	2 (1+1)
ENT 608	Acarology	2 (1+1)
ENT 609	Molecular Entomology	2 (1+1)
ENT 610	Integrated Pest Management	2 (2+0)
ENT 691	Doctoral Seminar – I	1 (0+1)
ENT 692	Doctoral Seminar – II	1 (0+1)
ENT 699	Doctoral Research	75 (0+75)

**Core courses for Doctoral programme.

Course Contents
Ph.D. in Plant Protection-Entomology

I. Course Title : Insect Phylogeny and Systematics
II. Course Code : ENT 601
III. Credit Hours : 3 (1+2)

IV. Aim of the course

To familiarize the students with different schools of classification, phylogenetics, classical and molecular methods, evolution of different groups of insects. Detailed study about the International Code of Zoological Nomenclature; ethics and procedure for taxonomic publications.

V. Theory

Unit I

Detailed study of three schools of classification- numerical, evolutionary and cladistic. Methodologies employed. Development of phenograms, cladograms, molecular approaches for the classification of organisms. Methods in identification of homology. Species concepts, speciation processes and evidences. Zoogeography.

Unit II

Study of different views on the evolution of insects- alternative phylogenies of insects: Kukalova Peck and Kristensen. Fossil insects and evolution of insect diversity over geological times.

Unit III

Detailed study of International Code of Zoological Nomenclature, including appendices to ICZN; scientific ethics. Nomenclature and documentation protocols and procedures; report preparation on new species; deposition of holotypes, paratypes, and insect specimens as a whole in national and international repositories – requirements and procedures.

Unit IV

Concept of Phylocode and alternative naming systems for animals. A detailed study of selected representatives of taxonomic publications – small publications of species descriptions, works on revision of taxa, monographs, check lists, faunal volumes, etc. Websites related to insect taxonomy and databases. Molecular taxonomy, barcoding species and the progress made in molecular sytematics.

VI. Practical

- Collection, curation and study of one taxon of insects- literature search, compilation of a checklist, study of characters, development of character table, and construction of taxonomic keys for the selected group;
- Development of descriptions, photographing, writing diagrams, and preparation of specimens for "type like" preservation, Submission of the collections made of the group;

- Multivariate analysis techniques for clustering specimens into different taxa, and development of phenograms;
- Rooting and character polarization for developing cladograms and use of computer programmes to develop cladograms.

VII. Learning outcome

- Scholars are expected to understand the concepts of taxonomic hierarchy, study taxonomic characters, variations, intra-specific phenotypic plasticity; prepare taxonomic keys for specific groups and write taxonomic papers and reviews.
- Scholars should be able to identify insects of economic importance up to family/ generic levels and specialize in any one group of insects up to species level identification.

VIII. Suggested Reading

CSIRO 1990. *The Insects of Australia: A Text Book for Students and Researchers*. 2nd Ed. Vols. I and II, CSIRO. Cornell Univ. Press, Ithaca.

Dakeshott J and Whitten MA. 1994. *Molecular Approaches to Fundamental and Applied Entomology*. Springer-Verlag, Berlin.

Freeman S and Herron JC. 1998. *Evolutionary Analysis*. Prentice Hall, New Delhi.

Hennig W. 1960. *Phylogenetic Systematics*. Urbana Univ. Illinois Press, USA.

Hoy MA. 2003. *Insect Molecular Genetics: An Introduction to Principles and Applications*. 2nd Ed. Academic Press, New York.

Mayr E and Ashlock PD. 1991. *Principles of Systematic Zoology*. 2nd Ed. McGraw Hill, New York.

Mayr E.1969. *Principles of Systematic Zoology*. McGraw-Hill, New York.

Quicke DLJ. 1993. *Principles and Techniques of Contemporary Taxonomy*. Blackie Academic and Professional, London.

Ross HH. 1974. *Biological Systematics*. Addison Wesley Publ. Co., London.

Wiley EO. 1981. *Phylogenetics: The Theory and Practices of Phylogenetic Systematics for Biologists*. Columbia Univ. Press, USA.

I. Course Title : Insect Physiology and Nutrition

II. Course Code : ENT 602

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart knowledge to the students on detailed physiology of various secretory and excretory systems, moulting process, chitin synthesis, physiology of digestion, transmission of nerve impulses, nutrition of insects, pheromones, etc.

V. Theory

Unit I

Physiology and biochemistry of insect cuticle and moulting process. Biosynthesis of chitin, chitin-protein interactions in various cuticles, hardening of cuticlde.

Unit II

Digestive enzymes, digestive physiology in phytophagous, wood boring and wool feeding insects, efficiency of digestion and absorption, role of endosymbionts in insect nutrition, nutritional effects on growth and development; physiology of excretion and osmoregulation, water conservation mechanisms.

Unit III

Detailed physiology of nervous system, transmission of nerve impulses, neuro-transmitters and modulators. Production of receptor potentials in different types of sensilla, pheromones and other semiochemicals in insect life, toxins and defense mechanisms.

Unit IV

Endocrine system and insect hormones, physiology of insect growth and development- metamorphosis, polymorphism and diapause. Insect behaviour in IPM- Concept of super-normal stimuli and behavioural manipulation as potential tool in pest management, use of semio-chemicals, auditory stimuli and visual signals in pest management.

VI. Practical

- Preparation of synthetic diets for different groups of insects;
- Rearing of insects on synthetic, semi-synthetic and natural diets;
- Determination of co-efficient of utilization;
- Qualitative and quantitative profile of bio-molecules: practicing analytical techniques for analysis of free amino acids of haemolymph;
- Zymogram analyses of amylase;
- Determination of chitin in insect cuticle;
- Examination and count of insect haemocytes.

VII. Learning outcome

- The scholars are expected to have thorough theoretical and practical knowledge of insect physiology that can be made use of in practical/ applied entomological aspects.
- Understand how physiological systems in insects are integrated to maintain homeostasis.

VIII. Suggested Reading

Ananthkrishnan TN. (Ed.). 1994. *Functional Dynamics of Phytophagous Insects*. Oxford and IBH, New Delhi.

Bernays EA and Chapman RF. 1994. *Host-Plant Selection by Phytophagous Insects*. Chapman and Hall, London.

Kerkut GA and Gilbert LI. 1985. *Insect Physiology, Biochemistry and Pharmacology*. Vols. I-XIII. Pergamon Press, Oxford, New York.

Muraleedharan K. 1997. *Recent Advances in Insect Endocrinology*. Association for Advancement of Entomology, Trivandrum, Kerala.

Rockstein, M. 1978. *Biochemistry of Insects*, Academic Press.

Simpson, SJ. 2007. *Advances in Insect Physiology*, Vol. 33, Academic Press (Elsevier), London, UK.

I. Course Title : Insect Ecology and Diversity

II. Course Code : ENT 603

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart advanced practical knowledge of causal factors governing the distribution and abundance of insects and the evolution of ecological characteristics. Study insect-plant interactions; get acquainted with biodiversity and conservation.

V. Theory

Unit I

Characterization of distribution of insects- Indices of Dispersion, Taylor's Power law. Island Biogeography. Population dynamics- Life tables, Leslie Matrix, Stable age distribution, Population projections. Predator-Prey Models- Lotka-Volterra and Nicholson-Bailey Model. Crop Modeling- an introduction.

Unit II

Insect Plant Interactions. Fig-figwasp mutualism and a quantitative view of types of associations. Role of insects in the environment. Adaptations to terrestrial habitats. Evolution of insect diversity and role of phytophagy as an adaptive zone for increased diversity of insects. Evolution of resource harvesting organs, resilience of insect taxa and the sustenance of insect diversity- role of plants. Herbivory, pollination, predation, parasitism. Modes of insect-plant interaction, tri-trophic interactions. Evolution of herbivory, monophagy vs polyphagy. Role of plant secondary metabolites. Meaning of stress- plant stress and herbivory. Consequences of herbivory to plant fitness and response to stress. Constitutive and induced plant defenses. Host seeking behavior of parasitoids.

Unit III

Biodiversity and Conservation- RET species, Ecological Indicators. Principles of Population genetics, Hardy Weinberg Law, Computation of Allelic and Phenotypic frequencies, Fitness under selection, Rates of Evolution under selection. Foraging Ecology- Optimal foraging theory, Marginal Value Theorem, and Patch departure rules, central place foraging, Mean-variance relationship and foraging by pollinators, Nutritional Ecology.

Unit IV

Reproductive ecology- Sexual selection, Mating systems, Reproductive strategies – timing, egg number, reproductive effort, sibling rivalry and parent-offspring conflict. Agro-ecological vs Natural Ecosystems – Characterisation, Pest Control as applied ecology- case studies.

VI. Practical

- Methods of data collection under field conditions;
- Assessment of distribution parameters, Taylor's power law, Iwao's patchiness index, Index of Dispersion, etc.;
- Calculation of sample sizes by different methods;
- Fitting Poisson and Negative Binomial distributions and working out the data transformation methods;
- Hardy-Weinberg Law, Computation of Allelic and Phenotypic Frequencies – Calculation of changes under selection, Demonstration of genetic drift;
- Assessment of Patch Departure rules. Assessment of Resource size by female insects using a suitable insect model, fruit flies/ *Goniozus*/ Female Bruchids, etc.;
- A test of reproductive effort and fitness;
- Construction of Life tables and application of Leslie Matrix – population projections, Stable age distribution;
- Exercises in development of Algorithms for crop modeling;

VII. Learning outcome

- The scholar is expected to develop expertise in methods of data collection for insect population studies, data transformation for analyses, diversity estimates, assessing

distribution parameters, study the impact of abiotic and biotic factors on the distribution and abundance of insects.
- Should gain significant knowledge on construction of life tables and their analyses, assessment of resource size by female insects, reproductive effort and fitness.

VIII. Suggested Reading

Barbosa P and Letourneau DK. (Eds.). 1988. *Novel Aspects of Insect-Plant Interactions*. Wiley, London.

Elizabeth BA and Chapman RF. 1994. *Host-Plant Selection by Phytophagous Insects*. Chapman and Hall, New York.

Freeman S and Herron JC.1998. *Evolutionary Analysis*. Prentice Hall, New Delhi.

Gotelli NJ and Ellison AM. 2004. *A Primer of Ecological Statistics*. Sinauer Associates, Sunderland, MA.

Gotelli NJ. 2001. *A Primer of Ecology*. 3rd Ed., Sinauer Associates, Sunderland, MA, USA.

Krebs C. 1998. *Ecological Methodology*. 2nd Ed. Benjamin-Cummings Publ. Co., New York.

Krebs CJ. 2001 *Ecology: The Experimental Analysis of Distribution and Abundance*. 5th Ed. Benjamin-Cummings Publ. Co., New York.

Magurran AE. 1988. *Ecological Diversity and its Measurement*. Princeton University Press, Princeton.

Real LA and Brown JH. (Eds.). 1991. *Foundations of Ecology: Classic Papers with Commentaries*. University of Chicago Press, USA.

Southwood TRE and Henderson PA. 2000. *Ecological Methods*. 3rd Ed. Wiley Blackwell, London.

Strong DR, Lawton JH and Southwood R. 1984. *Insects on Plants: Community Patterns and Mechanism*. Harward University Press, Harward.

Wratten SD and Fry GLA. 1980. *Field and Laboratory Exercises in Ecology*. Arnold Publ., London.

I. Course Title : Insect Behaviour

II. Course Code : ENT 604

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To acquaint the students with a thorough understanding of how natural selection has led to various survival strategies manifested as behavior in insects.

V. Theory

Unit I

Defining Behaviour- Concept of umwelt, instinct, fixed action patterns, imprinting, complex behavior, inducted behavior, learnt behavior and motivation. History of Ethology- development of behaviorism and ethology, contribution of Darwin, Frisch, Tinbergen and Lorenz; Studying behavior- Proximate and Ultimate approaches, behavioural traits under natural selection, genetic control of behavior and behavioural polymorphism.

Unit II

Orientation- Forms of primary and secondary orientation including taxes and kinesis; Communication- primary and secondary orientation, responses to environmental stimuli, role of visual, olfactory and auditory signals in inter- and intra-specific communication, use of signals in defense, mimicry, polyphenism; evolution of signals.

Unit III

Reproductive behavior- mate finding, courtship, territoriality, parental care, parental investment, sexual selection and evolution of sex ratios; Social behavior- kin selection, parental manipulation and mutualism; Self organization and insect behavior.

Unit IV

Foraging- Role of different signals in host searching (plant and insects) and host acceptance, ovipositional behavior, pollination behavior, co-evolution of plants and insect pollinators. Behaviour in IPM- Concept of super-normal stimuli and behavioural manipulation as potential tool in pest management, use of semio-chemicals, auditory stimuli and visual signals in pest management.

VI. Practical

- Quantitative methods in sampling behavior;
- Training bees to artificial feeders;
- Sensory adaptation and habituation in a fly or butterfly model, physical cues used in host selection in a phytophagous insect, chemical and odour cues in host selection in phytophagous insect (DBM or gram pod borer), colour discrimination in honey bee or butterfly model, learning and memory in bees, role of self-organization in resource tracking by honeybees;
- Evaluation of different types of traps against fruit flies with respect to signals;
- Use of honey bees/ *Helicoverpa armigera* to understand behavioural polymorphism with respect to learning and response to pheromone mixtures, respectively.

VII. Learning outcome

- Scholars are expected to be well versed with the behavior and orientation of insects towards exploitation as a tool in IPM.

VIII. Suggested Reading

Ananthkrishnan TN. (Ed.). 1994. *Functional Dynamics of Phytophagous Insects*. Oxford and IBH, New Delhi.

Awasthi VB. 2001. *Principles of Insect Behaviour*. Scientific Publ., Jodhpur.

Bernays EA and Chapman RF. 1994. *Host-Plant Selection by Phytophagous Insects*. Chapman and Hall, London.

Brown LB. 1999. *The Experimental Analysis of Insect Behaviour*. Springer, Berlin.

Krebs JR and Davies NB. 1993. *An Introduction to Behavioural Ecology*. 3rd Ed. Chapman and Hall, London.

Manning A and Dawkins MS. 1992. *An Introduction to Animal Behaviour*. Cambridge University Press, USA.

Mathews RW and Mathews JR. 1978. *Insect Behaviour*. A Wiley-InterScience Publ. John Wiley and Sons, New York.

I. Course Title : Bio-inputs for Pest Management

II. Course Code : ENT 605

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To appraise the students with advanced techniques in handling of different bio-agents, modern methods of biological control and scope in cropping system-based pest management in agro-ecosystems.

V. Theory

Unit I

Scope of classical biological control and augmentative bio-control; introduction and handling of natural enemies; nutrition of entomophagous insects and their hosts, dynamics of bio-agents *vis-à-vis* target pest populations.

Unit II

Bio-inputs: mass production of bio-pesticides, mass culturing techniques of bio-agents, insectary facilities and equipments, basic standards of insectary, viable mass-production unit, designs, precautions, good insectary practices.

Unit III

Colonization, techniques of release of natural enemies, recovery evaluation, conservation and augmentation of natural enemies, survivorship analysis and ecological manipulations, large-scale production of bio-control agents, bankable project preparation.

Unit IV

Scope of genetically engineered microbes and parasitoids in biological control, genetics of ideal traits in bio-control agents for introgressing and for progeny selections, breeding techniques of bio-control agents.

VI. Practical

- Mass rearing and release of some commonly occurring indigenous natural enemies;
- Assessment of role of natural enemies in reducing pest populations;
- Testing side effects of pesticides on natural enemies;
- Effect of semio-chemicals on natural enemies, breeding of various bio-control agents, performance of efficiency analyses on target pests;
- Project document preparation for establishing a viable mass-production unit/ insectary;
- Observation of feeding behavior acts of predatory bugs/ beetles.

VII. Learning outcome

- Scholars are expected to learn the mass multiplication techniques of the more common and economically feasible natural enemies to be exploited under IPM programmes.
- They should be able to guide entrepreneurs for establishing a viable mass-production unit/ insectary.

VIII. Suggested Reading

Burges HD and Hussey NW. (Eds.). 1971. *Microbial Control of Insects and Mites.* Academic Press, London.

Coppel HC and James WM. 1977. *Biological Insect Pest Suppression.* Springer Verlag, Berlin.

De Bach P. 1964. *Biological Control of Insect Pests and Weeds.* Chapman and Hall, London.

Dhaliwal, GS and Koul O. 2007. *Biopesticides and Pest Management.* Kalyani Publishers, New Delhi.

Gerson H and Smiley RL. 1990. *Acarine Biocontrol Agents – An Illustrated Key and Manual.* Chapman and Hall, New York.

Huffakar CB and Messenger PS. 1976. *Theory and Practices of Biological Control.* Academic Press, London.

I. Course Title : Insecticide Toxicology and Residues

II. Course Code : ENT 606

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To acquaint the students with the latest advancements in the field of insecticide toxicology, biochemical and physiological target sites of insecticides, and pesticide resistance mechanisms in insects.

V. Theory

Unit I

Penetration and distribution of insecticides in insect systems; insecticide selectivity; factors affecting toxicity of insecticides. Modes of action of newer insecticide molecules; developments in bio-rational approaches; SPLAT; RNAi technology for pest management.

Unit II

Biochemical and physiological target sites of insecticides in insects; developments in biorationals, biopesticides and newer molecules; their modes of action and structural – activity relationships; advances in metabolism of insecticides.

Unit III

Joint action of insecticides; activation, synergism and potentiation.

Unit IV

Problems associated with pesticide use in agriculture: pesticide resistance; resistance mechanisms and resistant management strategies; pest resurgence and outbreaks; persistence and pollution; health hazards and other side effects.

Unit V

Estimation of insecticidal residues- sampling, extraction, clean-up and estimation by various methods; maximum residue limits (MRLs) and their fixation; bound and conjugated residues, effect on soil fertility; insecticide laws and standards, and good agricultural practices.

VI. Practical

- Residue sampling, extraction, clean-up and estimation of insecticide residues by various methods;
- Calculations and interpretation of data;
- Biochemical and biological techniques for detection of insecticide resistance in insects;
- Preparation of EC formulation using neem oil.

VII. Learning outcome

- Scholars are expected to be well versed with the latest technologies of bioassays, insecticide/ pesticide residue analysis and solving problems associated with insect resistance to insecticides.

VIII. Suggested Reading

Busvine JR. 1971. *A Critical Review on the Techniques for Testing Insecticides*. CABI, London.

Dhaliwal GS and Koul O. 2007. *Biopesticides and Pest Management*. Kalyani Publishers, New Delhi.

Hayes WJ and Laws ER. 1991. *Handbook of Pesticide Toxicology*. Academic Press, New York.

Ishaaya I and Degheele (Eds.). 1998. *Insecticides with Novel Modes of Action*. Narosa Publ. House, New Delhi.

Matsumura F. 1985. *Toxicology of Insecticides*. Plenum Press, New York.

O' Brien RD. 1974. *Insecticides Action and Metabolism*. Academic Press, New York.

Perry AS, Yamamoto I, Ishaaya I and Perry R. 1998. *Insecticides in Agriculture and Environment*. Narosa Publ. House, New Delhi.

Prakash A and Rao J. 1997. *Botanical Pesticides in Agriculture*. Lewis Publ., New York.

I. Course Title : Plant Resistance to Insects

II. Course Code : ENT 607

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To familiarize the students with recent advances in resistance of plants to insects and acquaint with the techniques for assessment and evaluation of resistance in crop plants.

V. Theory

Unit I

Importance of plant resistance, historical perspective, desirable morphological, anatomical and biochemical adaptations of resistance; assembly of plant species – gene pool; insect sources – behaviour in relation to host plant factors.

Unit II

Physical and chemical environment conferring resistance in plants, role of trypsin inhibitors and protease inhibitors in plant resistance; biochemistry of induced resistance – signal transduction pathways, methyl jasmonate pathways, polyphenol oxidase pathways, salicylic acid pathways; effects of induced resistance; exogenous application of elicitors.

Unit III

Biotechnological approaches in host plant resistance- genetic manipulation of secondary plant substances; incorporation of resistant gene in crop varieties; marker-aided selection in resistance breeding.

Unit IV

Estimation of plant resistance based on plant damage- screening and damage rating; evaluation based on insect responses; techniques and determination of categories of plant resistance; breakdown of resistance in crop varieties.

VI. Practical

- Understanding mechanisms of resistance for orientation, feeding, oviposition, etc., allelochemical bases of insect resistance;
- Macroculturing of test insects like aphids, leaf/ plant hoppers, mites and stored grain pests;
- Field screening- microplot techniques, infester row technique, spreader row technique and plant nurseries;
- Determination of antixenosis index, antibiosis index, tolerance index, plant resistance index.

VII. Learning outcome

- Scholars are expected to identify sources of resistance in different crops and varieties; their utilization in resistance breeding programmes involving screening techniques for specific pests.

VIII. Suggested Reading

Panda N. 1979. *Principles of Host Plant Resistance to Insects*. Allenheld, Osum and Co., New York.

Rosenthal GA and Janzen DH. (Eds.). 1979. *Herbivores – their Interactions with Secondary Plant Metabolites*. Vol. I, II. Academic Press, New York.

Sadasivam S and Thayumanavan B. 2003. *Molecular Host Plant Resistance to Pests*. Marcel Dekker, New York.

Smith CM, Khan ZR and Pathak MD. 1994. *Techniques for Evaluating Insect Resistance in Crop Plants*. CRC Press, Boca Raton, Florida.

I. Course Title : Acarology

II. Course Code : ENT 608

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To acquire a good working knowledge of identification of economically important groups of mites up to the species level, a detailed understanding of the newer acaricide molecules and utilization of predators.

V. Theory

Unit I

Comparative morphology of Acari, phylogeny of higher categories in mites, knowledge of commonly occurring orders and families of Acari in India. Diagnostic characteristics of commonly occurring species from families Tetranychidae, Tenuipalpidae, Eriophyidae, Tarsonemidae, Phytoseiidae, Bdellidae, Cunaxidae, Stigmaeidae, Pymotidae, Cheyletidae, Acaridae, Pyroglyphidae, Orthogalumnidae, Argasidae, Ixodidae, Sarcoptidae. Soil mites in India.

Unit II

Management of economical important species of mites in agriculture, veterinary and public health; storage acarology.

Unit III

Mites as vectors of plant pathogens; mode of action, structure-activity relationships of different groups of acaricides; problem of pesticide resistance in mites, resurgence of mites.

Unit IV

Predatory mites, their mass production and utilization in managing mite pests, acaropathogenic fungi- identification, isolation and utilization.

VI. Practical

- Identification of commonly occurring mites up to species, preparation of keys for identification;
- Collection of specific groups of mites and preparing their identification keys;
- Rearing phytoseiid mites and studying their role in suppression of spider mites;
- Management of mite pests of crops using acaricides, phytoseiid predators, fungal pathogens, etc.

VII. Learning outcome

- Scholars should be able to identify major mite pests, their management and predatory mites that can be used in biological control.
- They are also expected to learn the rearing techniques of predatory Phytoseiid mites.

VIII. Suggested Reading

Evans GO.1992. *Principles of Acarology*. CABI, London.
Gerson H and Smiley RL. 1990. *Acarine Bio-control Agents- An Illustrated Key and Manual*. Chapman and Hall, New York.
Gupta SK. 1985. *Handbook of Plant Mites of India*. Zoological Survey of India, Calcutta.
Krantz GW. 1970. *A Manual of Acarology*. Oregon State University Book Stores, Corvallis, Oregon.
Sadana GL. 1997. *False Spider Mites Infesting Crops in India*. Kalyani Publ. House, New Delhi.

I. Course Title : Molecular Entomology
II. Course Code : ENT 609
III. Credit Hours : 2 (1+1)

IV. Aim of the course

To familiarize the students with DNA recombinant technology, marker genes, transgenic plants, and biotechnological advances in sericulture and apiculture.

V. Theory

Unit I

Introduction to molecular biology; techniques used in molecular biology.

Unit II

DNA and RNA analysis in insects- transcription and translocation mechanisms. DNA recombinant technology, identification of genes/ nucleotide sequences for characters of interest. Genetic improvement of natural enemies. Cell lines, genetic engineering in baculoviruses, *Bt* and entomopathogenic fungi.

Unit III

Genes of interest in entomological research- marker genes for sex identification, neuropeptides, JH esterase, St toxins and venoms, chitinase, CPTI; lectins and proteases. Transgenic plants for pest resistance and diseases.

Unit IV

Insect gene transformation; biotechnology in relation to silkworms and honey bees; introduction of lectin genes for pest suppression; DNA finger printing for taxonomy and phylogeny. Genetic improvement of inebriate tolerance of natural enemies.

Unit V

DNA-based diagnostics; insect immune systems in comparison to vertebrates; molecular basis of metamorphosis; Sf transgenic technology and implications; molecular biology of baculoviruses; insecticide resistance. Resistance management strategies in transgenic crops.

VI. Practical

- Isolation of DNA/ RNA;
- Purity determinations, purification of total DNA from animal tissues;
- Base pair estimation;

- Agarose gel electrophoresis;
- Quantitative enzyme profile of alimentary canal;
- Restriction mapping of DNA;
- Demonstration of PCR, RFLP and RAPD techniques.

VII. Learning outcome

- The scholars are expected to have mastered the molecular techniques applicable in entomological research like isolation of insect DNA, purification, DNA barcoding and utilizing these techniques in molecular systematics and biological control aspects.

VIII. Suggested Reading

Bhattacharya TK, Kumar P and Sharma A. 2007. *Animal Biotechnology*. 1st Ed., Kalyani Publication, New Delhi.

Hagedon HH, Hilderbrand JG, Kidwell MG and Law JH. 1990. *Molecular Insect Science*. Plenum Press, New York.

Hoy MA. 2003. *Insect Molecular Genetics: An Introduction to Principles and Applications*. 2nd Ed. Academic Press, New York.

Oakeshott J and Whitten MA. 1994. *Molecular Approaches to Fundamental and Applied Entomology*. Springer Verlag.

Rechcigl JE and Rechcigl NA. 1998. *Biological and Biotechnological Control of Insect Pests*. Lewis Publ., North Carolina.

Roy U and Saxena V. 2007. *A Hand Book of Genetic Engineering*. 1st Ed., Kalyani Publishers, New Delhi.

Singh BD. 2008. *Biotechnology* (*Expanding Horizons*). Kalyani Publishers, New Delhi.

Singh P. 2007. *Introductory to Biotechnology*. 2nd Ed. Kalyani Publishers, New Delhi.

I. Course Title : Integrated Pest Management

II. Course Code : ENT 610

III. Credit Hours : 2 (2+0)

IV. Aim of the course

To acquaint the students with recent concepts of integrated pest management; surveillance and data base management; successful national and international case histories of integrated pest management, non-conventional tools in pest management.

V. Theory

Unit I

Principles of sampling and surveillance, database management and computer programming; simulation techniques, system analysis and modeling.

Unit II

Study of case histories of national and international programmes, their implementation, adoption and criticism; global trade and risk of invasive pests; updating knowledge on insect outbreaks and their management.

Unit III

Genetic engineering and new technologies- their progress and limitations in IPM programmes, deployment of benevolent alien genes for pest management- case studies; scope and limitations of bio-intensive and ecological based IPM programmes; application of IPM to farmers' real time situation.

Unit IV

Challenges, needs and future outlook; dynamism of IPM under changing cropping systems and climate; insect pest management under protected cultivation; strategies for pesticide resistance management.

VI. Learning outcome

- Having gained sufficient experience in advanced studies of IPM the scholars should be able to independently frame IPM schedules for major crops/ cropping ecosystems (cereal/ pulse crop/ oilseed crop based/ vegetable crop based agro-ecosystems).

VII. Suggested Reading

Dhaliwal GS and Arora R. 2003. *Integrated Pest Management – Concepts and Approaches.* Kalyani Publishers, New Delhi.

Dhaliwal GS, Singh R and Chhillar BS. 2006. *Essentials of Agricultural Entomology*. Kalyani Publishers, New Delhi.

Flint MC and Bosch RV. 1981. *Introduction to Integrated Pest Management*. Springer, Berlin.

Koul O and Cuperus GW. 2007. *Ecologically Based Integrated Pest Management.* CABI, London.

Koul O, Dhaliwal GS and Curperus GW. 2004. *Integrated Pest Management –Potential, Constraints and Challenges.* CABI, London.

Maredia KM, Dakouo D and Mota-Sanchez D. 2003. *Integrated Pest Management in the Global Arena.* CABI, London.

Metcalf RL and Luckman WH. 1982. *Introduction to Insect Pest Management.* John Wiley and Sons, New York.

Norris RF, Caswell-Chen EP and Kogan M. 2002. *Concepts in Integrated Pest Management.* Prentice Hall, New Delhi.

Pedigo RL. 1996. *Entomology and Pest Management*. Prentice Hall, New Delhi.

Subramanyam B and Hagstrum DW. 1995. *Integrated Management of Insects in Stored Products.* Marcel Dekker, New York.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Protection
– Plant Pathology

Course Title with Credit Load
M.Sc. in Plant Pathology

Course Code	Course Title	Credit Hours
PL PATH 501*	Mycology	2+1
PL PATH 502*	Plant Virology	2+1
PL PATH 503*	Plant Pathogenic Prokaryotes	2+1
PL PATH 504*	Plant Nematology	2+1
PL PATH 505*	Principles of Plant Pathology	2+1
PL PATH 506*	Techniques in Detection and Diagnosis of Plant Diseases	0+2
PL PATH 507	Principles of Plant Disease Management	2+1
PL PATH 508	Epidemiology and Forecasting of Plant Diseases	1+0
PL PATH 509	Disease Resistance in Plants	2+0
PL PATH 510	Ecology of Soil-borne Plant Pathogens	1+1
PL PATH 511	Chemicals and Botanicals in Plant Disease Management	2+1
PL PATH 512	Detection and Management of Seed Borne Pathogens	2+1
PL PATH 513	Biological Control of Plant Diseases	1+1
PL PATH 514	Integrated Disease Management	2+1
PL PATH 515*	Diseases of Field and Medicinal Crops	2+1
PL PATH 516	Diseases of Fruits, Plantation and Ornamental Crops	2+1
PL PATH 517	Diseases of Vegetable and Spices Crops	2+1
PL PATH 518	Post Harvest Diseases	2+1
PL PATH 519	Plant Quarantine and Regulatory Measures	1+0
PL PATH 591	Master's Seminar	0+1
PL PATH 521	Master's Research	0+30

*Core Courses for Master's

Course Contents
M.Sc. in Plant Pathology

I. Course Title : Mycology
II. Course Code : PL PATH 501
III. Credit Hours : 2+1

IV. Aim of the course

To study the nomenclature, classification and characters of fungi.

V. Theory

Unit I

Introduction, definition of different terms, basic concepts. Importance of mycology in agriculture, relation of fungi to human affairs. History of mycology. Importance of culture collection and herbarium of fungi. Somatic characters and reproduction in fungi. Modern concept of nomenclature and classification, Classification of kingdom fungi: Stramenopila and Protists.

Unit II

The general characteristics of protists and life cycle in the Phyla Plasmodiophoromycota, Dictyosteliomycota, Acrasiomycota and Myxomycota. Kingdom Stramenopila: characters and life cycles of respective genera under Hypochytriomycota, Oomycota and Labyrinthulomycota.

Unit III

Kingdom fungi: General characters, ultrastructure and life cycle patterns in representative genera under Chytridiomycota, Zygomycota, Ascomycota; Archiascomycetes, Ascomycetous yeasts, Pyrenomycetes, Plectomycetes, Discomycetes, Loculoascomycetes, Erysiphales and anamorphs of ascomycetous fungi.

Unit IV

Basidiomycota; general characters, mode of reproduction, types of basidiocarps and economic importance of Hymenomycetes. Uridinales and Ustilaginales; variability, host specificity and life cycle pattern in rusts and smuts. Mitosporic fungi; status of asexual fungi, their teliomorphic relationships, Molecular characterization of plant pathogenic fungi.

VI. Practical

- Detailed comparative study of different groups of fungi;
- Collection of cultures and live specimens;
- Saccardoan classification and classification based on conidiogenesis;
- Vegetative structures and different types of fruiting bodies produced by slime molds, stramenopiles and true fungi;
- Myxomycotina: Fructification, plasmodiocarp, sporangia, plasmodium and aethalia. Oomycota;

- Somatic and reproductive structures of *Pythium*, *Phytophthora*, downy mildews and *Albugo*, Zygomycetes: Sexual and asexual structures of *Mucor*, *Rhizopus*, General characters of VAM fungi. Ascomycetes; fruiting structures, Erysiphales, and Eurotiales;
- General identification characters of Pyrenomycetes, Discomycetes, Loculo-ascomycetes and Laboulbenio-mycetes, Basidiomycetes; characters, ultrastructures and life cycle patterns in Ustilaginomycetes and Teliomycetes, Deuteromycetes;
- Characters of Hyphomycetes and Coelomycetes and their teliomorphic and anamorphic states, Collection, preservation, culturing and identification of plant parasitic fungi;
- Application of molecular approaches and techniques for identification of fungal pathogens.

VII. Suggested Reading

Ainsworth GC, Sparrow FK and Susman HS. 1973. *The Fungi – An Advanced Treatise*. Vol. IV (A & B). Academic Press, New York.

Alexopoulos CJ, Mims CW and Blackwell M.2000. *Introductory Mycology*. 5th Ed. John Wiley & Sons, New York.

Maheshwari R. 2016. *Fungi: Experimental Methods in Biology* 2nd edn. CRC Press, US.

Mehrotra RS and Arneja KR. 1990. *An Introductory Mycology*. Wiley Eastern, New Delhi.

Sarbhoy AK. 2000. *Text book of Mycology*. ICAR, New Delhi.

Singh RS. 1982. *Plant Pathogens – The Fungi*. Oxford & IBH, New Delhi.

Webster J. 1980. *Introduction to Fungi*. 2nd Ed. Cambridge Univ. Press, Cambridge, New York.

I. Course Title : Plant Virology

II. Course Code : PL PATH 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with the structure, virus- vector relationship, biology and management of plant viruses.

V. Theory

Unit I

History and economic significances of plant viruses. General and morphological characters, composition and structure of viruses. Myco-viruses, arbo and baculo viruses, satellite viruses, satellite RNAs, phages, viroids and prions**.** Origin and evolution of viruses and their nomenclature and classification.

Unit II

Genome organization, replication in selected groups of plant viruses and their movement in host. Response of the host to virus infection: biochemical, physiological, and symptomatical changes. Transmission of viruses and virus-vector relationship. Isolation and purification of viruses.

Unit III

Detection and identification of plant viruses by using protein and nucleic acid based diagnostic techniques. Natural (R-genes) and engineering resistance to plant viruses.

Unit IV

Virus epidemiology and ecology (spread of plant viruses in fields, host range and survival). Management of diseases caused by plant viruses.

VI. Practical

- Study of symptoms caused by plant viruses (followed by field visit);
- Isolation and biological purification of plant virus cultures;
- Bioassay of virus cultures on indicator plants and host differentials;
- Transmission of plant viruses (Mechanical, graft and vector and study of disease development);
- Plant virus purification (clarification, concentration, centrifugation, high resolution separation and analysis of virions), Electron microscopy for studying viral particle morphology;
- Antisera production, Detection and diagnosis of plant viruses with serological (ELISA), nucleic acid (Non-PCR–LAMP, Later flow micro array and PCR based techniques);
- Exposure to basic bio-informatic tools for viral genome analysis and their utilization in developing detection protocols and population studies (BLASTn tool, Primer designing software, Bioedit tool, Claustal X/W, MEGA Software).

VII. Suggested Reading

Bos L. 1964. *Symptoms of Virus Diseases in Plants*. Oxford & IBH., New Delhi.

Brunt AA, Krabtree K, Dallwitz MJ, Gibbs AJ and Watson L. 1995. *Virus of Plants: Descriptions and Lists from VIDE Database*. CABI, Wallington.

Gibbs A and Harrison B. 1976. *Plant Virology – The Principles*. Edward Arnold, London. Hull R. 2002. *Mathew's Plant Virology*. 4th Ed. Academic Press, New York.

Noordam D. 1973. *Identification of Plant Viruses, Methods and Experiments*. Oxford & IBH, New Delhi.

Wilson C. 2014. *Applied Plant Virology*. CABI Publishing England.

I. Course Title : Plant Pathogenic Prokaryotes

II. Course Code : PL PATH 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with plant pathogenic prokaryote (procarya) and their structure, nutritional requirements, survival and dissemination.

V. Theory

Unit I

Prokaryotic cell: History and development of Plant bacteriology, history of plant bacteriology in India. Evolution of prokaryotic life, Prokaryotic cytoskeletal proteins. Structure of bacterial cell. Structure and composition of gram negative and gram positive cell wall; synthesis of peptidoglycan; Surface proteins; Lipopolysaccaride structure; Membrane transport; fimbrae and pili (Type IV pili); Mechanism of flagellar rotatory motor and locomotion, and bacterial movement; Glycocalyx (S-layer; capsule); the bacterial chromosomes and plasmids; Operon and other structures in cytoplasm; Morphological feature of fastidious bacteria, spiroplasmas and Phytoplasmas.

Unit II

Growth and nutritional requirements. Infection mechanism, role of virulence factors in expression of symptoms. Survival and dispersal of phytopathogenic prokaryotes.

Unit III

Taxonomy of phytopathogenic prokarya: Taxonomic ranks hierarchy; Identification, Classification and nomenclature of bacteria, phytoplasma and spiroplasma. The codes of Nomenclature and characteristics. Biochemical and molecular characterization of phytopathogenic prokaryotes.

Unit IV

Variability among phytopathogenic prokarya: general mechanism of variability (mutation); specialized mechanisms of variability (sexual like process in bacteria-conjugation; transformation; transduction); and horizontal gene transfer.

Unit V

Bacteriophages, L form of bacteria, plasmids and bdellovibrios: Structure; Infection of host cells; phage multiplication cycle; Classification of phages, Use of phages in plant pathology/ bacteriology, Lysogenic conversion; H Plasmids and their types, plasmid borne phenotypes.Introduction to bacteriocins. Strategies for management of diseases caused by phytopathogenic prokaryotes.

VI. Practical

- Study of symptoms produced by phytopathogenic prokaryotes;
- Isolation, enumeration, purification, identification and host inoculation of phytopathogenic bacteria;
- Stains and staining methods;
- Biochemical and serological characterization;
- Isolation of genomic DNA plasmid;
- Use of antibacterial chemicals/ antibiotics;
- Isolation of fluorescent *Pseudomonas*;
- Preservation of bacterial cultures;
- Identification of prokaryotic organisms by using 16S rDNA, and other gene sequences;
- Diagnosis and management of important diseases caused by bacteria and mollicutes.

VII. Suggested Reading

Goto M. 1990. *Fundamentals of Plant Bacteriology*. Academic Press, New York.

Jayaraman J and Verma JP. 2002. *Fundamentals of Plant Bacteriology*. Kalyani Publishers, Ludhiana.

Mount MS and Lacy GH. 1982. *Phytopathogenic Prokaryotes*. Vols. I, II Academic Press, New York.

Salle AJ. 1979. *Fundamental Principles of Bacteriology 7th edn.*

Verma JP, Varma A and Kumar D. (Eds). 1995. *Detection of Plant Pathogens and their Management*. Angkor Publ., New Delhi.

I. Course Title : Plant Nematology

II. Course Code : PL PATH 504

III. Credit Hours : 2+1

IV. Aim of the course

To project the importance of nematodes in agriculture and impart basic knowledge on all aspects of plant nematology.

V. Theory

Unit I

Characteristics of Phylum Nematoda and its relationship with other related phyla, history and growth of Nematology; nematode habitats and diversity- plant, animal and human parasites; useful nematodes; economic importance of nematodes to agriculture, horticulture and forestry.

Unit II

Gross morphology of plant parasitic nematodes; broad classification, nematode biology, physiology and ecology.

Unit III

Types of parasitism; nature of damage and general symptomatology; interaction of plant-parasitic nematodes with other organisms.

Unit IV

Plant nematode relationships, cellular responses to infection by important phytonematodes; physiological specialization among phytonematodes.

Unit V

Principles and practices of nematode management; integrated nematode management.

Unit VI

Emerging nematode problems, Importance of nematodes in international trade and quarantine.

VI. Practical

- Studies on kinds of nematodes- free-living, animal, insect and plant parasites;
- Nematode extraction from soil;
- Extraction of migratory endoparasites, staining for sedentary endoparasites;
- Examination of different life stages of important plant parasitic nematodes, their symptoms and histopathology.

VII. Suggested Reading

Dropkin VH. 1980. *An Introduction to Plant Nematology*. John Wiley & Sons, New York.

Maggenti AR. 1981. *General Nematology*. Springer-Verlag, New York.

Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed. CABI Publishing: Wallingford, UK.

Perry RN, Moens M, and Starr JL. 2009. *Root-knot nematodes*, CABI Publishing: Wallingford, UK.

Sikora RA, Coyne D, Hallman J and Timper P. 2018. *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture.*3rd edn. CABI Publishing, England.

Thorne G. 1961. *Principles of Nematology*. McGraw Hill, New Delhi.

Walia RK and Bajaj HK. 2003. *Text Book on Introductory Plant Nematology*. ICAR, New Delhi.

Walia RK and Khan MR. 2018. *A Compendium of Nematode Diseases of Crop Plants*, ICAR-AICRP (Nematodes), IARI, New Delhi.

I. Course Title : Principles of Plant Pathology

II. Course Code : PL PATH 505

III. Credit Hours : 2+1

IV. Aim of the course

To introduce the subject of Plant Pathology, its concepts and principles.

V. Theory

Unit I

Importance, definitions and concepts of plant diseases, history and growth of plant pathology, biotic and abiotic causes of plant diseases.

Unit II

Growth, reproduction, survival and dispersal of important plant pathogens, role of environment and host nutrition on disease development.

Unit III

Host parasite interaction, recognition concept and infection, symptomatology, disease development- role of enzymes, toxins, growth regulators; defense strategies- oxidative burst; Phenolics, Phytoalexins, PR proteins, Elicitors. Altered plant metabolism as affected by plant pathogens.

Unit IV

Genetics of resistance; 'R' genes; mechanism of genetic variation in pathogens; molecular basis for resistance; marker-assisted selection; genetic engineering for disease resistance.

VI. Practical

- Basic plant pathological techniques;
- Isolation, inoculation and purification of plant pathogens and proving Koch's postulates;
- Techniques to study variability in different plant pathogens;
- Purification of enzymes, toxins and their bioassay;
- Estimation of growth regulators, phenols, phytoalexins in resistant and susceptible plants.

VII. Suggested Reading

Agrios GN. 2005. *Plant Pathology*. 5th Ed. Academic Press, New York.

Heitefuss R and Williams PH. 1976. *Physiological Plant Pathology*. Springer Verlag, Berlin, New York.

Mehrotra RS and Aggarwal A. 2003. *Plant Pathology*. 2nd Ed. Oxford & IBH, New Delhi.

Singh RP. 2012. *Plant Pathology* 2nd edn. Kalyani Publishers, New Delhi.

Singh RS. 2017. *Introduction to Principles of Plant Pathology*. 5th edn. MedTech, New Delhi.

Singh DP and Singh A. 2007. *Disease and Insect Resistance in Plants.* Oxford & IBH, New Delhi.

Upadhyay RK. and Mukherjee KG. 1997. *Toxins in Plant Disease Development and Evolving Biotechnology*. Oxford & IBH, New Delhi.

I. Course Title : Techniques for Detection and Diagnosis of Plant Diseases

II. Course Code : PL PATH 506

III. Credit Hours : 0+2

IV. Aim of the course

To impart training on various methods/ techniques/ instruments used in the study of plant diseases/ pathogens.

V. Practical

- Detection of plant pathogens 1. Based on visual symptoms, 2. Biochemical test 3.

Using microscopic techniques, 4. Cultural studies; (use of selective media to isolate pathogens). 5. Biological assays (indicator hosts, differential hosts) 6. Serological assays 7. Nucleic acid based techniques (Non-PCR–LAMP, Later flow microarray and PCR based- multiplex, nested, qPCR, immune capture PCR, etc.);

- Phenotypic and genotypic tests for identification of plant pathogens;
- Molecular identification (16S rDNA and 16s-23S rDNA intergenic spacer region sequences-prokaryotic organisms; and eukaryotic organism by ITS region) and whole genome sequencing;
- Volatile compounds profiling by using GC-MS and LC-MS;
- FAME analysis, Fluorescence *in-situ* Hybridization (FISH), Flow Cytometry, Phage display technique, biosensors for detection of plant pathogens;
- Genotypic tools such as genome/ specific gene sequence homology comparison by BLAST (NCBI and EMBL) and electron microscopy techniques of plant virus detection and diagnosis.

VI. Suggested Reading

Baudoin ABAM, Hooper GR, Mathre DE and Carroll RB. 1990. *Laboratory Exercises in Plant Pathology: An Instructional Kit*. Scientific Publ., Jodhpur.

Dhingra OD and Sinclair JB. 1986. *Basic Plant Pathology Methods*. CRC Press, London, Tokyo. Fox RTV. 1993. *Principles of Diagnostic Techniques in Plant Pathology,* CABI Wallington.

Forster D and Taylor SC. 1998. *Plant Virology Protocols: From Virus Isolation to Transgenic Resistance. Methods in Molecular Biology*. Humana Press, Totowa, New Jersey.

Mathews REF. 1993. *Diagnosis of Plant Virus Diseases*. CRC Press, Boca Raton, Tokyo.

Matthews REF. 1993. *Diagnosis of Plant Virus Diseases*. CRC Press, Florida.

Noordam D. 1973. *Identification of Plant Viruses, Methods and Experiments*. Cent. Agic. Pub. Doc. Wageningen.

Pathak VN. 1984. *Laboratory Manual of Plant Pathology*. Oxford & IBH, New Delhi.

Trigiano RN, Windham MT and Windham AS. 2004. *Plant Pathology-Concepts and Laboratory Exercises*. CRC Press, Florida.Chakravarti BP. 2005. *Methods of Bacterial Plant Pathology*. Agrotech, Udaipur.

I. Course Title : Principles of Plant Disease Management

II. Course Code : PL PATH 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with different strategies for management of plant diseases.

V. Theory

Unit I

Principles of plant disease management by cultural, physical, biological, chemical, organic amendments and botanicals methods of plant disease control, integrated control measures of plant diseases. Disease resistance and molecular approach for disease management.

Unit II

History of fungicides, bactericides, antibiotics, concepts of pathogen, immobilization, chemical protection and chemotherapy, nature, properties and mode of action of antifungal, antibacterial and antiviral chemicals. Label claim of fungicides.

Unit III

Application of chemicals on foliage, seed and soil, role of stickers, spreaders and other adjuvants, health *vis-a-vis* environmental hazards, residual effects and safety measures

VI. Practical

- Phytopathometry;
- Methods of *in-vitro* evaluation of chemicals, antibiotics, bio agents against plant pathogens;
- Field evaluation of chemicals, antibiotics, bio agents against plant pathogens;
- Soil solarisation, methods of soil fumigation under protected cultivation;
- Methods of application of chemicals and bio control agents;
- ED and MIC values, study of structural details of sprayers and dusters;
- Artificial epiphytotic and screening of resistance.

VII. Suggested Reading

Fry WE. 1982. *Principles of Plant Disease Management*. Academic Press, New York.

Hewitt HG. 1998. *Fungicides in Crop Protection*. CABI, Wallington. Marsh RW. 1972. Systemic Fungicides. Longman, New York.

Nene YL and Thapliyal PN. 1993. *Fungicides in Plant Disease Control*. Oxford & IBH, New Delhi.

Palti J. 1981. *Cultural Practices and Infectious Crop Diseases*. Springer Verlag, New York.

Vyas SC. 1993 *Handbook of Systemic Fungicides*. Vols. I-III. Tata McGraw Hill, New Delhi.

I. Course Title : Epidemiology and Forecasting of Plant Diseases

II. Course Code : PL PATH 508

III. Credit Hours : 1+0

IV. Aim of the course

To acquaint with the principles of epidemiology and its application in disease forecasting.

V. Theory

Unit I

Epidemic concepts, simple interest and compound interest disease, historical development. Elements of epidemics and their interaction.Structures and patterns of epidemics. Modelling, system approaches and expert systems in plant pathology.

Unit II

Genetics of epidemics. Models for development of plant disease epidemics. Common and natural logarithms, function fitting, area under disease progress curve and correction factors, inoculum dynamics. Population biology of pathogens, temporal and spatial variability in plant pathogens.

Unit III

Epidemiological basis of disease management. Survey, surveillance and vigilance. Remote sensing techniques and image analysis. Crop loss assessment.

Unit IV

Principles and pre-requisites of forecasting, systems and factors affecting various components of forecasting, some early forecasting and procedures based on weather and inoculum potential, modelling disease growth and disease prediction. Salient features of important forecasting models.

VI. Suggested Reading

Campbell CL and Madden LV. 1990. *Introduction to Plant Disease Epidemiology*. John Wiley & Sons, New York

Cooke B, Jones DM and Gereth KB. 2018 *The Epidemiology of Plant Diseases*. Springer Publications.
Cowling EB and Horsefall JG. 1978. *Plant Disease*. Vol. II. Academic Press, New York.
Laurence VM, Gareth H and Frame Van den Bosch (Eds.). *The Study of Plant Disease Epidemics*. APS, St. Paul, Minnesota.
Nagarajan S and Murlidharan K. 1995. *Dynamics of Plant Diseases*. Allied Publ., New Delhi.
Thresh JM. 2006. *Plant Virus Epidemiology*. Advances in Virus Research 67, Academic Press, New York.
Van der Plank JE. 1963. *Plant Diseases Epidemics and Control*. Academic Press, New York.
Zadoks JC and Schein RD. 1979. *Epidemiology and Plant Disease Management*. Oxford Univ. Press, London.

I. Course Title : Disease Resistance in Plants
II. Course Code : PL PATH 509
III. Credit Hours : 2+0

IV. Aim of the course

To acquaint with the disease resistance mechanisms.

V. Theory

Unit I

Introduction and historical development, dynamics of pathogenicity, process of infection, variability in plant pathogens, gene centres as sources of resistance, disease resistance terminologies. Disease escape,non-host resistance and disease tolerance.

Unit II

Genetic basis of disease resistance, types of resistance, identification of physiological races of pathogen, disease progression in relation to resistance, stabilizing selection pressure in plant pathogens.

Unit III

Host defence system, morphological and anatomical resistance, pre-formed chemicals in host defence, post infectional chemicals in host defence, phytoalexins, hypersensitivity and its mechanisms. Genetic basis of relationships between pathogen and host, Gene-for-gene concept, protein-for-protein and immunization basis, management of resistance genes. Strategies for gene deployment.

VI. Suggested Reading

Deverall BJ. 1977. *Defence Mechanisms in Plants*. Cambridge Univ. Press, Cambridge, New York.
Mills Dallice *et al.*1996. *Molecular Aspects of Pathogenicity and Resistance: Requirement for Signal Transduction*. APS, St Paul, Minnesota.
Parker J. 2008. *Molecular Aspects of Plant Diseases Resistance*. Blackwell Publ.
Robinson RA. 1976. *Plant Pathosystems*. Springer Verlag, New York.
Singh BD. 2005. *Plant Breeding – Principles and Methods*. 7th Ed. Kalyani Publishers, Ludhiana
Van der Plank JE. 1975. *Principles of Plant Infection*. Academic Press, New York.
Van der Plank JE. 1978. *Genetic and Molecular Basis of Plant Pathogenesis*. Springer Verlag. New York.
Van der Plank JE. 1982. *Host Pathogen Interactions in Plant Disease*. Academic Press, New York.
Van der Plank JE. 1984. *Disease Resistance in Plants*. Academic Press, New York.

I. Course Title : Ecology of Soil Borne Plant Pathogens

II. Course Code : PL PATH 510

III. Credit Hours : 1+1

IV. Aim of the course

To provide knowledge on soil-plant disease relationship.

V. Theory

Unit I

Soil as an environment for plant pathogens, nature and importance of rhizosphere and rhizoplane, host exudates, soil and root inhabiting fungi. Interaction of microorganisms.

Unit II

Types of biocontrol agents. Inoculum potential and density in relation to host and soil variables, competition, predation, antibiosis and fungistasis. Conducive and suppressive soils.

Unit III

Biological control- concepts and potentialities for managing soil borne pathogens. Potential of *Trichoderma* and fluorescent *Pseudomonas* in managing plant diseases.

VI. Practical

- Quantification of rhizosphere and rhizoplane microflora with special emphasis on pathogens;
- Pathogenicity test by soil and root inoculation techniques, correlation between inoculum density of test pathogens and disease incidence, demonstration of fungistasis in natural soils;
- Suppression of test soil-borne pathogens by antagonistic microorganisms;
- Isolation and identification of different biocontrol agents;
- Study of various plant morphological structures associated with resistance, testing the effect of root exudates and extracts on spore germination and growth of plant pathogens;
- Estimating the phenolic substances, total reducing sugars in susceptible and resistant plants;
- Estimating the rhizosphere and root tissue population of microorganisms (pathogens) in plants.

VII. Suggested Reading

Baker KF and Snyder WC. 1965. *Ecology of Soil-borne Plant Pathogens*. John Wiley, New York.

Cook RJ and Baker KF. 1983. *The Nature and Practice of Biological Control of Plant Pathogens*. APS, St Paul, Minnesota.

Garret SD. 1970. *Pathogenic Root-infecting Fungi*. Cambridge Univ. Press,Cambridge, New York.

Hillocks RJ and Waller JM. 1997. *Soil-borne Diseases of Tropical Crops*. CABI, Wallington.

Mondia JL and Timper P 2016. Interactions of microfungi and plant parasitic nematodes. In: *Biology of Microfungi* (De-Wei-Lei Ed.). Springer Publications

Parker CA, Rovira AD, Moore KJ and Wong PTN. (Eds). 1983. *Ecology and Management of Soil-borne Plant Pathogens*. APS, St. Paul, Minnesota.

I. Course Title : Chemicals and Botanicals in Plant Disease Management

II. Course Code : PL PATH 511

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on the concepts, principles and judicious use of chemicals and botanicals in plant disease management.

V. Theory

Unit I

History and development of chemicals; definition of pesticides and related terms; advantages and disadvantages of chemicals and botanicals.

Unit II

Classification of chemicals used in plant disease management and their characteristics.

Unit III

Chemicals in plant disease control, viz., fungicides, bactericides, nematicides, antiviral chemicals and botanicals. Issues related to label claim.

Unit IV

Formulations, mode of action and application of different fungicides; chemotherapy and phytotoxicity of fungicides.

Unit V

Handling, storage and precautions to be taken while using fungicides; compatibility with other agrochemicals, persistence, cost-benefit ratio, factor affecting fungicides. New generation fungicides and composite formulations of pesticides.

Unit VI

Efficacy of different botanicals used and their mode of action. Important botanicals used against diseases. General account of plant protection appliances; environmental pollution, residues and health hazards, fungicidal resistance in plant pathogens and its management.

VI. Practicals

- Acquaintance with formulation of different fungicides and plant protection appliances;
- Formulation of fungicides, bactericides and nematicides;
- *In-vitro* evaluation techniques, preparation of different concentrations of chemicals including botanical pesticides against pathogens;
- Persistence, compatibility with other agro-chemicals;
- Detection of naturally occurring fungicide resistant mutants of pathogen;
- Methods of application of chemicals.

VII. Suggested Reading

Bindra OS and Singh H. 1977. *Pesticides – And Application Equipment*. Oxford & IBH, New Delhi.

Nene YL and Thapliyal PN. 1993. *Fungicides in Plant Disease Control*. 3rd edn. Oxford & IBH, New Delhi.

Torgeson DC. (Ed.). 1969. *Fungicides*. Vol. II. An Advanced Treatise. Academic Press, New York.

Vyas SC. 1993. *Handbook of Systemic Fungicides*. Vols. I-III. Tata McGraw Hill, New Delhi.

I. Course Title : Detection and Management of Seed Borne Pathogens
II. Course Code : PL PATH 512
III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with seed-borne diseases, their nature, detection, transmission, epidemiology, impacts/ losses and management.

V. Theory

Unit I

History and economic importance of seed pathology in seed industry, plant quarantine and SPS under WTO. Morphology and anatomy of typical monocotyledonous and dicotyledonous infected seeds.

Unit II

Recent advances in the establishment and subsequent cause of disease development in seed and seedling. Localization and mechanism of seed transmission in relation to seed infection, seed to plant transmission of pathogens.

Unit III

Seed certification and tolerance limits, types of losses caused by seed-borne diseases in true and vegetatively propagated seeds, evolutionary adaptations of crop plants to defend seed invasion by seed-borne pathogens. Epidemiological factors influencing the transmission of seed-borne diseases, forecasting of epidemics through seed-borne infection.

Unit IV

Production of toxic metabolites affecting seed quality and its impact on human, animal and plant health, management of seed-borne pathogens/ diseases and procedure for healthy seed production. Seed health testing, methods for detecting microorganism.

VI. Practical

- Conventional and advanced techniques in the detection and identification of seed-borne fungi, bacteria and viruses;
- Relationship between seed-borne infection and expression of the disease in the field.

VII. Suggested Reading

Agarwal VK and Sinclair JB. 1993. *Principles of Seed Pathology*. Vols. I & II, CBS Publ., New Delhi.

Hutchins JD and Reeves JE. (Eds.). 1997. *Seed Health Testing: Progress Towards the 21st Century*. CABI, Wallington.

Paul Neergaard. 1988. *Seed Pathology*. McMillan, London.

Suryanarayana D. 1978. *Seed Pathology*. Vikash Publ., New Delhi.

I. Course Title : Biological Control of Plant Pathogens
II. Course Code : PL PATH 513
III. Credit Hours : 1+1

IV. Aim of the course

To study principles and application of ecofriendly and sustainable management strategies of plant diseases.

V. Theory

Unit I

Concept of biological control, definitions, importance, principles of plant disease management with bioagents, history of biological control, merits and demerits of biological control.

Unit II

Types of biological interactions, competition: mycoparasitism, exploitation for hypovirulence, rhizosphere colonization, competitive saprophytic ability, antibiosis, induced resistance, mycorrhizal associations, operational mechanisms and its relevance in biological control.

Unit III

Factors governing biological control, role of physical environment, agroecosystem, operational mechanisms and cultural practices in biological control of pathogens, pathogens and antagonists and their relationship, biocontrol agents, comparative approaches to biological control of plant pathogens by resident and introduced antagonists, control of soil-borne and foliar diseases. Compatibility of bioagents with agrochemicals and other antagonistic microbes.

Unit IV

Commercial production of antagonists, their delivery systems, application and monitoring, biological control in IDM, IPM and organic farming system, biopesticides available in market. Quality control system of biocontrol agents.

VI. Practical

- Isolation, characterization and maintenance of antagonists, methods of study of antagonism and antibiosis, application of antagonists against pathogen *in-vitro and in vivo* conditions;
- Preparation of different formulations of selected bioagents and their mass production;
- Quality parameters of biocontrol agents;
- One week exposure visit to commercial biocontrol agents production unit.

VII. Suggested Reading

Campbell R. 1989. *Biological Control of Microbial Plant Pathogens*. Cambridge Univ. Press, Cambridge.

Cook RJ and Baker KF. 1983. *Nature and Practice of Biological Control of Plant Pathogens*. APS, St. Paul, Minnesota.

Fokkemma MJ. 1986. *Microbiology of the Phyllosphere*. Cambridge Univ. Press, Cambridge.

Gnanamanickam SS (Eds). 2002. *Biological Control of Crop Diseases*. CRC Press, Florida.

Heikki MT and Hokkanen James M. (Eds.). 1996. *Biological Control – Benefits and Risks*. Cambridge Univ. Press, Cambridge.

Mukerji KG, Tewari JP, Arora DK and Saxena G. 1992. *Recent Developments in Biocontrol of Plant Diseases*. Aditya Books, New Delhi.

I. Course Title : Integrated Disease Management

II. Course Code : PL PATH 514

III. Credit Hours : 2+1

IV. Aim of the course

To emphasize the importance and the need of IDM in the management of diseases of important crops.

V. Theory

Unit I

Introduction, definition, concept and tools of disease management, components of integrated disease management- their limitations and implications.

Unit II

Development of IDM-basic principles, biological, chemical and cultural disease management.

Unit III

IDM in important crops- rice, wheat, cotton, sugarcane, chickpea, rapeseed and mustard, pearl millet, pulses, vegetable crops, fruit, plantation and spice crops.

VI. Practical

- Application of physical, biological and cultural methods;
- Use of chemical and biocontrol agents, theircompatibility and integration in IDM.Demonstration of IDM and multiple disease management in crops of regional importance as project work.

VII. Suggested Reading

Gupta VK and Sharma RC. (Eds). 1995. *Integrated Disease Management and Plant Health*. Scientific Publ., Jodhpur.

Mayee CD, Manoharachary C, Tilak KVBR, Mukadam DS and Deshpande Jayashree (Eds.). 2004. *Biotechnological Approaches for the Integrated Management of Crop Diseases*. Daya Publ. House, New Delhi.

Sharma RC and Sharma JN. (Eds). 1995. *Integrated Plant Disease Management*. Scientific Publ., Jodhpur.

I. Course Title : Diseases of Field and Medicinal Crops

II. Course Code : PL PAT 515

III. Credit Hours : 2+1

IV. Theory

Unit I

Diseases of Cereal crops- Rice, wheat, barley, pearl millet, sorghum and maize.

Unit II

Diseases of Pulse crops- Gram, urdbean, mungbean, lentil, pigeonpea, soybean and cowpea.

Unit III

Diseases of Oilseed crops- Rapeseed and mustard, sesame, linseed, sunflower, groundnut, castor.

Unit IV

Diseases of Cash crops- Cotton, sugarcane.

Unit V

Diseases of Fodder legume crops- Berseem, oats, guar, lucerne.

Unit VI

Medicinal crops- *Plantago*, liquorice, mulathi, rosagrass, sacred basil, mentha, ashwagandha, *Aloe vera*.

V. Practical

- Detailed study of symptoms and host parasite relationship of important diseases of above mentioned crops;
- Collection and dry preservation of diseased specimens of important crops.

Suggested Reading

Joshi LM, Singh DV and Srivastava KD. 1984. *Problems and Progress of Wheat Pathology in South Asia*. Malhotra Publ. House, New Delhi.

Rangaswami G. 1999. *Diseases of Crop Plants in India*. 4th Ed. Prentice Hall of India, New Delhi.

Ricanel C, Egan BT, Gillaspie Jr AG and Hughes CG. 1989. *Diseases of Sugarcane, Major Diseases*. Academic Press, New York.

Singh RS. 2017. *Plant Diseases*. 10th Ed. Medtech, New Delhi.

Singh US, Mukhopadhyay AN, Kumar J and Chaube HS. 1992. *Plant Diseases of Internatiobnal Importance*. Vol. I. *Diseases of Cereals and Pulses*. Prentice Hall, Englewood Cliffs, New Jersey.

I. Course Title : Diseases of Fruits, Plantation and Ornamental Crops

II. Course Code : PL PTH 516

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with diseases of fruits, plantation, ornamental plants and their management.

V. Theory

Unit I

Introduction, symptoms and etiology of different fruit diseases. Factors affecting disease development in fruits like apple, pear, peach, plum, apricot, cherry, walnut, almond, strawberry, citrus, mango, grapes, guava, ber, banana, pineapple, papaya, fig, pomegranate, date palm, custard apple and their management.

Unit II

Symptoms, mode of perpetuation of diseases of plantation crops such as tea, coffee, rubber and coconut and their management.

Unit III

Symptoms and life cycle of pathogens. Factors affecting disease development of ornamental plants such as roses, gladiolus, tulip, carnation, gerbera orchids, marigold, chrysanthemum and their management.

VI. Practical

- Detailed study of symptoms and host parasite relationship of representative diseases of plantation crops;
- Collection and dry preservation of diseased specimens of important crops.

VII. Suggested Reading

Gupta VK and Sharma SK. 2000. *Diseases of Fruit Crops*. Kalyani Publishers, New Delhi.

Pathak VN. 1980. *Diseases of Fruit Crops*. Oxford & IBH, New Delhi.

Singh RS. 2000. *Diseases of Fruit Crops*. Oxford & IBH, New Delhi.

Walker JC. 2004. *Diseases of Vegetable Crops*. TTPP, India.

I. Course Title : Diseases of Vegetable and Spices Crops

II. Course Code : PL PATH 517

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about symptoms, epidemiology of different diseases of vegetables and spices and their management.

V. Theory

Unit I

Nature, prevalence, factors affecting disease development of tuber, bulb, leafy vegetable, crucifers, cucurbits and solanaceaous vegetables. Diseases of crops under protected cultivation.

Unit II

Symptoms and management of diseases of different root, tuber, bulb, leafy vegetables, crucifers, cucurbits and solanaceaous vegetable crops.

Unit III

Symptoms, epidemiology and management of diseases of different spice crops such as black pepper, nutmeg, saffron, cumin, coriander, turmeric, fennel, fenugreek and ginger. Biotechnological approaches in developing disease resistant transgenics.

VI. Practical

- Detailed study of symptoms and host pathogen interaction of important diseases of vegetable and spice crops.

VII. Suggested Reading

Chaube HS, Singh US, Mukhopadhyay AN and Kumar J. 1992. *Plant Diseases of International Importance*. Vol. II. *Diseases of Vegetable and Oilseed Crops*. Prentice Hall, Englewood Cliffs, New Jersey.

Gupta VK and Paul YS. 2001. *Diseases of Vegetable Crops*. Kalyani Publishers, New Delhi

Gupta SK and Thind TS. 2006. *Disease Problem in Vegetable Production*. Scientific Publ., Jodhpur.

Sherf AF and Mcnab AA. 1986. *Vegetable Diseases and their Control*. Wiley Inter Science, Columbia.

Singh RS. 1999. *Diseases of Vegetable Crops*. Oxford & IBH, New Delhi.

Walker JC. 1952. *Diseases of Vegetable Crops*. McGraw-Hill, New York.

I. Course Title : Post-Harvest Diseases

II. Course Code : PL PATH 518

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint with the post-harvest diseases of agricultural produce and their eco-friendly management.

V. Theory

Unit I

Concept of post-harvest diseases, definitions, importance with reference to management and health, principles of plant disease management as pre-harvest and post-harvest, Types of post-harvest problems both by biotic and abiotic factors.

Unit II

Role of physical environment, agro-ecosystem leading to quiescent infection, operational mechanisms and cultural practices in perpetuation of pathogens, pathogens and antagonist and their relationship, role of biocontrol agents and chemicals in controlling post-harvest diseases, comparative approaches to control of plant pathogens by resident and introduced antagonists.

Unit III

Integrated approaches in controlling diseases and improving the shelf life of produce using nutritional, bio-control agents and other agents, control of aflatoxigenic and mycotoxigenic fungi, application and monitoring for health hazards.

Unit IV

Study of symptoms, toxicosis of various pathogens, knowledge of Codex Alimentarious for each product and commodity. Physical and biological agents/ practices responsible for development/ prevention of post-harvest diseases-traditional and improved practices.

VI. Practical

- Isolation, characterization and maintenance of post-harvest pathogens, application of antagonists against pathogens *in vivo* condition;
- Comparative efficacy of different fungicides and bioagents;
- Study of different post-harvest disease symptoms on cereals, pulses, oilseed, commercial crops, vegetables, fruits and flowers;
- Visit to cold storage.

VII. Suggested Reading

Chaddha KL and Pareek OP. 1992. *Advances in Horticulture* Vol. IV, Malhotra Publ. House, New Delhi.

Pathak VN. 1970. *Diseases of Fruit Crops and their Control*. IBH Publ., New Delhi.

I. Course Title : Plant Quarentine and Regulations

II. Course Code : PL PATH 519

III. Credit Hours : 1+0

IV. Aim of the course

To acquaint the learners about the principles and the role of plant quarantine in containment of pests and diseases, plant quarantine regulations and set-up.

V. Theory

Unit I

Historical development in plant quarantine, Definitions of pest, and transgenics as per Govt. notification; Organizational set up of plant quarantine in India. relative importance; quarantine – domestic and international. Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case histories of exotic pests/ diseases and their status.

Unit II

Acts related to registration of pesticides and transgenics. History of quarantine legislations, Salient features of PQ Order 2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

Unit III

Identification of pest/ disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniques to detect pest/ pathogen infestations; VHT and other safer techniques of disinfestation/ salvaging of infected material.

Unit IV

WTO regulations; non-tariff barriers; Pest risk analysis, good laboratory practices for pesticide laboratories; pesticide industry; Sanitary and Phytosanitary measures. Visit to plant quarantine station and PEQ facilities.

Suggested Reading

Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.

Rhower GG. 1991. Regulatory Plant Pest Management. In: *Handbook of Pest Management in Agriculture*. 2nd Ed. Vol. II. (Ed. David Pimental). CRC Press.

Course Course Title with Credit Load
Ph.D. in Plant Pathology

Course Code	Course Title	Credits Hours
PL PATH 601	Advances in Mycology	2+1
PL PATH 602	Advances in Virology	2+1
PL PATH 603	Advances in Plant Pathogenic Prokaryotes	2+1
PL PATH 604**	Molecular Basis of Host-pathogen Interaction	2+1
PL PATH 605	Principles and Procedures of Certification	1+0
PL PATH 606	Plant Biosecurity and Biosafety	2+0
PL PATH 691	Doctoral Seminar – I	0+ 1
PL PATH 692	Doctoral Seminar – II	0+ 1
PL PATH 699	Doctoral Research	0+75

**Core Courses for Doctoral Programme

Course Contents
Ph.D. in Plant Pathology

I. Course Title : Advances in Mycology
II. Course Code : PL PATH 601
III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with the advances in mycology

V. Theory

Unit I

General introduction, historical development and advances in mycology. Recent taxonomic criteria, morphological criteria for classification. Serological, chemical (chemotaxonomy), molecular and numerical (computer based assessment) taxonomy. Interaction between groups: Phylogeny, Micro conidiation, conidiogenesis and sporulating structures of fungi imperfecti.

Unit II

Population biology, pathogenic variability/ vegetative compatibility. Heterokaryosis and parasexual cycle. Sex hormones in fungi. Pleomorphism and speciation in fungi. Mechanism of nuclear inheritance. Mechanism of extra-nuclear inheritance. Biodegradation.

Unit III

Ultra structures and chemical constituents of fungal cells, functions of cell organelles. Mitosis, meiosis, gene action and regulation. Effects of fungal interaction with host plants and other microorganisms; parasitism, symbiosis and commensalism.

Unit IV

Genetic Improvement of Fungal strains. Fungal biotechnology. Fungi mediated synthesis of nano particles – characterization process and application. Mycotoxins problems and its management.

VI. Practical

- Isolation, purification and identification of cultures, spores and mating type determination;
- Study of conidiogenesis-Phialides, porospores, arthospores;
- Study of fruiting bodies in Ascomycotina;
- Identification of fungi up to species level;
- Study of hyphal anastomosis;
- Morphology of representative plant pathogenic genera form different groups of fungi;
- Molecular characterization of fungi.

VII. Suggested Reading

Alexopoulos CJ, Mims CW and Blackwell M. 1996. *Introductory Mycology*. John Wiley & Sons, New York.

Dube HC. 2005. *An Introduction to Fungi*. 3rd Ed. Vikas Publ. House, New Delhi.
Kirk PM, Cannon PF, David JC and Stalpers JA. (Eds.). 2001. *Ainsworth and Bisby's Dictionary of Fungi*. 9th Ed., CABI, Wallington.
Maheshwari R. 2016. *Fungi: Experimental Methods in Biology* 2nd edn. CRC Press, US.
Ulloa M and Hanlin RT. 2000. *Illustrated Dictionary of Mycology*. APS, St. Paul, Minnesota.
Webster J and Weber R. 2007. *Introduction to Fungi*. Cambridge University Press, Cambridge.

I. Course Title : Advances in Plant Virology

II. Course Code : PL PATH 602

III. Credit Hours : 2+1

IV. Aim of the course

To educate about the advanced techniques and new developments in plant virology.

V. Theory

Unit I

Origin, evolution and interrelationship with animal viruses. Virus morphology, structure, architecture, replication (overview of host and viral components required), assembly and virus specific cytological effects in infected plant cells. Mechanisms leading to the evolution of new viruses/ strains: mutation, recombination, pseudo-recombination, component re-assortment, etc.

Unit II

Major vector groups of plant viruses and their taxonomy, virus-vector relationship, molecular mechanism of virus transmission by vectors. Terminologies used in immunology and serology. Classification, structure and functions of various domains of Immunoglobulins. Production of Polyclonal and monoclonal antibodies for detection of viruses. Immuno/ serological assays (Slide agglutination tests, Test tube precipitation test, Double agar diffusion test, ELISA (DAC, DAS, TAS), Dot Immuno Binding Assay, and nucleic acid based assays for detection of plant viruses.

Unit III

Polymerase Chain Reaction based (PCR, reverse transcriptase PCR, multiplex PCR, Nested PCR, Real time/ q PCR) and non PCR based: LAMP, Fluorescent *in situ* hybridization (FISH), dot blot hybridization. Plant virus genome organization (General properties of plant viral genome- information content, coding and non-coding regions), replication, transcription and translational strategies of pararetroviruses, geminiviruses, tobamo-, poty-, bromo, cucumo, ilar, tospoviruses, satellite viruses and satellite RNA.

Unit IV

Gene expression, regulation and viral promoters.Genetic engineering with plant viruses, viral suppressors, RNAi dynamics and resistant genes. Virus potential as vectors, genetically engineered resistance, transgenic plants. Techniques and application of tissue culture for production of virus free planting materials. Phylogenetic grouping system based on partial/ complete sequences of virus genomes and using of next generation sequencing technology in plant virus discovery.

VI. Practical

- Purification of viruses, SDS-PAGE for molecular weight determination, production of polyclonal antiserum, purification of IgG and conjugate preparation;
- Acquaintance with different serological techniques (i) DAC- ELISA (ii) DAS-ELISA

(iii) DIBA (iv) Western blots (v) (ab) 2-ELISA. Nucleic acid isolation, DOT-blot, southern hybridization, probe preparation,and autoradiography;
- PCR application and viral genome cloning of PCR products, plasmid purification, enzyme digestion, sequencing, annotation of genes, analysis of viral sequences (use of gene bank, blast of viral sequences and phylogeny);
- Bioinformatics analysis tools for virology (ORF finder, Gene mark, Gene ontology, BLAST, Clustal X/W, Tm pred and Phylogeny programs).

VII. Suggested Reading

Davies 1997. *Molecular Plant Virology: Replication and Gene Expression*. CRC Press, Florida.
Fauquet *et al*. 2005. *Virus Taxonomy*. VIII Report of ICTV. Academic Press, New York.
Gibbs A and Harrison B. 1976. *Plant Virology – The Principles*. Edward Arnold, London.
Jones P, Jones PG and Sutton JM. 1997. *Plant Molecular Biology: Essential Techniques*. John Wiley & Sons, New York.
Khan J A and Dijkstra. 2002. *Plant Viruses as Molecular Pathogens*. Howarth Press, New York.
Maramorosch K, Murphy FA and Shatkin AJ. 1996. *Advances in Virus Research*. Vol. 46. Academic Press, New York.
Pirone TP and Shaw JG. 1990. *Viral Genes and Plant Pathogenesis*. Springer Verlag, New York.
Roger Hull. 2002. *Mathew's Plant Virology* (4th Ed.). Academic Press, New York.
Thresh JM. 2006. *Advances in Virus Research*. Academic Press, New York.

I. Course Title : Advances in Plant Pathogenic Prokaryotes
II. Course Code : PL PATH 603
III. Credit Hours : 2+1

IV. Aim of the course

To learn about the latest developments in all the plant pathogenic prokaryotes as a whole.

V. Theory

Unit I

Prokaryotic cell: Molecular basis for **o**rigin and evolution of prokaryotic life, RNA world, prokaryotic cytoskeletal proteins. Flagella structure, assembly and regulation. Structure and composition **(bacteria)** cell wall/ envelop, Types of secretion systems (TI to TIV) and their molecular interaction, fimbriae and pili (Type IV pili), Bacterial chromosomes and plasmids, other cell organelles. Growth, nutrition and metabolism in prokaryotes (Embden-Meyerhof-Parmas (EMP) pathway, Phosphoketolase Pathway and Entner Doudoroff Pathway).

Unit II

Current trends in taxonomy and identification of phytopathogenic prokarya**:** International code of nomenclature, Polyphasic approach, New/ special detection methods for identification of bacterial plant pathogens. Taxonomic ranks hierarchy; Identification, Advances in classification and nomenclature.

Unit III

Bacterial genetics**:** General mechanism of variability (mutation), specialized mechanisms of variability. Transposable genetic elements in bacteria-integron and prophages, Mechanism of gene transfer. Pathogenicity islands, horizontal gene transfer, Bacterial Pan-Genome.

Unit IV

Bacteriophages: Composition, structure and infection. Classification and use of phages in plant pathology/ bacteriology. Host pathogen interactions: Molecular mechanism of pathogenesis: Pathogenicity factors of soft rot, necrosis, wilt, canker, etc. Immunization, induced resistance/ Systemic Acquired Resistance, Quorum sensing. Bacterial pathogenicity and virulence: Molecular mechanism of virulence and pathogenesis, bacterial secretion systems, pathogenicity of bacterial enzymes that degrade the cell walls, Role of hrp/ hrc genes and TALE effectors. Synthesis and regulation of EPSs.

Unit V

Beneficial Prokaryotes-Endophytes, PGPR, Phylloplane bacteria and their role in disease management. Endosymbionts for host defence. Advances in management of diseases caused by prokaryotes: genetic engineering, RNA silencing; CRISPR cas9.

VI. Practical

- Pathogenic studies and race identification, plasmid profiling of bacteria, fatty acid profiling of bacteria, RFLP profiling of bacteria and variability status, Endospore, Flagella staining, Test for secondary metabolite production, cyanides, EPS, siderophore, specific detection of phytopathogenic bacteria using species/ pathovar specific primers;
- Basic techniques in diagnostic kit development, Molecular tools to identify phytoendosymbionts;
- Important and emerging diseases and their management strategies.

VII. Suggested Reading

Dale JW and Simon P. 2004. *Molecular Genetics of Bacteria*. John Wiley & Sons, New York.

Garrity GM, Krieg NR and Brenner DJ. 2006. *Bergey's Manual of Systematic Bacteriology: The Proteobacteria*. Vol. II. Springer Verlag, New York.

Gnanamanickam SS. 2006. *Plant-Associated Bacteria*. Springer Verlag, New York.

Mount MS and Lacy GH. 1982. *Plant Pathogenic Prokaryotes*. Vols. I, II. Academic Press, New York.

Sigee DC. 1993. *Bacterial Plant Pathology: Cell and Molecular Aspects*. Cambridge Univ. Press, Cambridge.

Starr MP. 1992. *The Prokaryotes*. Vols. I–IV. Springer Verlag, New York.

I. Course Title : Molecular Basis of Host-pathogen Interaction

II. Course Code : PL PATH 604

III. Credit Hours : 2+1

IV. Aim of the course

To understand the concepts of molecular biology and biotechnology in relation to host plant- pathogen interactions.

V. Theory

Unit I

History of host plant resistance and importance to Agriculture. Importance and role of biotechnological tools in plant pathology. Basic concepts and principles to study host pathogen relationship. Molecular genetics, imaging and analytical chemistry tools for studying plants, microbes, and their interactions.

Unit II

Different forms of plant-microbe interactions and nature of signals/ effectors underpinning these interactions. Plant innate immunity: PAMP/ DAMP. Molecular basis of host-pathogen interaction-fungi, bacteria, viruses and nematodes; recognition system, signal transduction.

Unit III

Induction of defence responses- HR, Programmed cell death, reactive oxygen species, systemic acquired resistance, induced systemic resistance, pathogenesis related proteins, phytoalexins and virus induced gene silencing. Molecular basis of gene-for-gene hypothesis; R-gene expression and transcription profiling, mapping and cloning of resistance genes and marker-aided selection, pyramiding of R genes. Gene for gene systems: Background, genetics, phenotypes, molecular mechanisms, races, breakdown of resistance (boom-and-bust cycles), Coevolution-arms race and trench warfare models, Metapopulations, cost of resistance, cost of unnecessary virulence, GFG in agricultural crops vs. natural populations, Durability of resistance, erosion of quantitative resistance.

Unit IV

Pathogen population genetics and durability, viruses vs cellular pathogens.Gene deployment, cultivar mixtures. Disease emergence, host specialization. Circadian clock genes in relation to innate immunity. Biotechnology and disease management; development of disease resistance plants using genetic engineering approaches, different methods of gene transfer, biosafety issues related to GM crops.

VI. Practical

- Protein, DNA and RNA isolation, plasmid extraction, PCR analysis, DNA and Protein electrophoresis, bacterial transformation;
- Gene mapping and marker assisted selection;
- Development and use of molecular markers in identification and characterization of resistance to plant pathogens and their management.

VII. Suggested Reading

Chet I. 1993. *Biotechnology in Plant Disease Control*. John Wiley & Sons, New York.

Gurr SJ, McPohersen MJ and Bowlos DJ. (Eds.). 1992. *Molecular Plant Pathology – A Practical Approach*. Vols. I & II, Oxford Univ. Press, Oxford.

Mathew JD. 2003. *Molecular Plant Pathology*. Bios Scientific Publ., UK.

Ronald PC. 2007. *Plant-Pathogen Interactions: Methods in Molecular Biology*. Humana Press, New Jersey.

Stacey G and Keen TN. (Eds.). 1996. *Plant Microbe Interactions*. Vols. I-III. Chapman & Hall, New York; Vol. IV. APS Press, St. Paul, Minnesota.

I. Course Title : Principles and Procedures of Certification

II. Course Code : PL PATH 605

III. Credit Hours : (1+0)

IV. Aim of the course

To acquaint with the certification procedures of seed and planting material.

V. Theory

Unit I

Introduction to certification. International scenario of certification and role of ISTA, EPPO, OECD, etc. in certification and quality control. Case studies of certification systems of USA and Europe. National Regulatory mechanism and certification system including seed certification, minimum seed certification standards. National status of seed health in seed certification. Methods for testing genetic identity, physical purity, germination percentage, seed health, etc. Fixing tolerance limits for diseases and insect pests in certification and quality control programmes.

Unit II

Methods used in certification of seeds, vegetative propagules and *in-vitro* cultures. Accreditation of seed testing laboratories. Role of seed/ planting material health certification in national and international trade.

VI. Reference

Association of Official Seed Certifying Agencies. Hutchins D and Reeves JE. (Eds.). 1997.

Seed Health Testing: Progress Towards the 21st Century. CABI, UK. ISHI-veg Manual of Seed Health Testing Methods.

ISHI-F Manual of Seed Health Testing Methods.

ISTA Seed Health Testing Methods.

Tunwar NS and Singh SV. 1988. Indian Minimum Seed Certification Standards. Central Seed Certification Board, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi. US National Seed Health System.

e-Resources

http://www.aosca.org/index.htm.

http://www.worldseed.org/enus/international_seed/ishi_vegetable.html

http://www.worldseed.org/en-us/international _seed/ ishi_f.html

http://www.seedtest.org/en/content—1—1132—241.html

http://www.seedhealth.org

I. Course Title : Plant Biosecurity and Biosafety

II. Course Code : PATH 606

III. Credit Hours : 2+0

IV. Aim of the course

To facilitate deeper understanding on plant biosecurity and biosafety issues in agriculture.

V. Theory

Unit I

History of biosecurity, Concept of biosecurity, Components of biosecurity, Quarantine, Invasive Alien Species, Biowarfare, Emerging/ resurgence of pests and diseases. Introduction and History of biosecurity and its importance.

Unit II

National Regulatory Mechanism and International Agreements/ Conventions, viz., Agreement on Application of Sanitary and Phytosanitary (SPS) Measures. World Trade Organization (WTO), Convention on Biological Diversity (CBD), International Standards for Phytosanitary Measures, pest risk analysis, risk assessment models, pest information system, early warning and forecasting system, use of Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/ disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity.

Unit III

Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, Issues related to release of genetically modified crops. Emerging/ resurgence of pests and diseases in the changing scenario of climatic conditions. Issues related to release of genetically modified crops.

VI. Suggested Reading

Biosecurity: A Comprehensive Action Plan.

Biosecurity Australia.

Biosecurity for Agriculture and Food Production.

FAO Biosecurity Toolkit 2008.

Grotto Andrew J and Jonathan B Tucker. 2006. Biosecurity Guidance.

Khetarpal RK and Kavita Gupta 2006. Plant Biosecurity in India – Status and Strategy. Asian Biotechnology and Development Review **9**(2): 3963.

Randhawa GJ, Khetarpal RK, Tyagi RK and Dhillon BS (Eds.). 2001. Transgenic Crops and Biosafety Concerns. NBPGR, New Delhi.

e-Resources

http://www.inspection.gc.ca/english/anima/heasan/fad/biosecure.*sht ml*

www.fao.org/docrep/010/a1140e/a1140e00.htm Laboratory

http://www.who.int/csr/resources/publications/biosafety/WHO_CD S_EPR_2006.pdf

http://www.americanprogress.org/kf/biosecurity_ a_comprehensive_ action_plan.pdf

www.biosecurity.govt.nz DEFRA. www.defra.gov.uk/animalh/diseases/control/biosecurity/index.htm

www.daff.gov.au/ba;www.affa.gov.au/biosecurityaustralia Biosecurity New Zealand.

http://www.fao.org/biosecurity/ CFIA.

VII. List of Journals

- *Annals of Applied Biology* – Cambridge University Press, London
- *Annals of Plant Protection Sciences*- Society of Plant Protection, IARI, New Delhi
- *Annual Review of Phytopathology* – Annual Reviews, Palo Alto, California
- *Annual Review of Plant Pathology* – Scientific Publishers, Jodhpur
- *Canadian Journal of Plant Pathology* – Canadian Phytopathological Society, Ottawa
- *Indian Journal of Biotechnology* – National Institute of Science Communication and Information Resources, CSIR, New Delhi
- *Indian Journal of Mycopathological Research* – Indian Society of Mycology, Kolkata.
- *Indian Journal of Plant Protection* – Plant Protection Association of India, NBPGR, Hyderabad.
- *Indian Journal of Virology* – Indian Virological Society, New Delhi
- *Indian Phytopathology*-Indian Phytopathological Society, IARI New Delhi.
- Journal of Mycology and Plant Pathology – Society of Mycology and Plant Pathology, Udaipur.
- *Journal of Plant Disease Science*- Association of Plant Pathologists (Central India) PDKV, Akola.
- *Journal of Phytopathology* – Blackwell Verlag, Berlin
- *Mycologia* – New York Botanical Garden, Pennsylvania
- *Mycological Research* – Cambridge University Press, London
- *Physiological Molecular Plant Pathology* – Academic Press, London – *Phytopathology* – American Phytopathological Society, USA
- *Plant Disease* – The American Phytopathological Society, USA
- *Plant Disease Research* – Indian Society of Plant Pathologists, Ludhiana
- *Plant Pathology* – British Society for Plant Pathology, Blackwell Publ.

- *Review of Plant Pathology* – CAB International, Wallingford
- *Virology*- New York Academic Press e-Resources
- www.shopapspress.org
- www.apsjournals.apsnet.org
- www.apsnet.org/journals
- www.cabi_publishing.org
- www.springer.com/life+Sci/agriculture
- www.backwellpublishing.com
- www.csiro.au
- www.annual-reviews.org

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Plant Protection
– Nematology

Course Title with Credit Load
M.Sc. in Nematology

Course Code	Course Title	Credit Hours
NEMA 501*	Principles of Nematology	2+1
NEMA 502$/ ENT 503	Principles of Taxonomy	2+0
NEMA 503*	Structural Organization of Nematodes	2+1
NEMA 504*	Nematode Systematics	2+1
NEMA 505*	Nematological Techniques	1+2
NEMA 506*	Nematode Diseases of Crops	3+1
NEMA 507	Nematode Biology and Physiology	2+1
NEMA 508	Nematode Ecology	2+1
NEMA 509	Nematode Interactions with Other Organisms	2+1
NEMA 510*	Nematode Management	2+1
Nema 511	Beneficial Nematodes	1+1
NEMA 512/ ENT 510$	Principles of Integrated Pest Management	1+1
NEMA 513/ PL PATH 513@	Disease Resistance in Plants	2+0
NEMA 514/ ENT 520$	Plant Quarantine, Biosafety and Biosecurity	2+0
NEMA 515/ PATH 521/ ENT 524	IPM in Protected Cultivation	2+1
NEMA 591	Master's Seminar	1+0
NEMA 599	Master's Research	0+30

*Core Courses for Master's

Course Contents
M.Sc. in Nematology

I. Course Title : Principles of Nematology
II. Course Code : NEMA 501
III. Credit Hours : 2+1

IV. Aim of the course

To project the importance of nematodes in agriculture and impart basic knowledge on all aspects of plant nematology.

V. Theory

Unit I

Characteristics of Phylum Nematoda and its relationship with other related phyla, history and growth of Nematology; nematode habitats and diversity- plant, animal and human parasites; useful nematodes; economic importance of nematodes to agriculture, horticulture and forestry.

Unit II

Gross morphology of plant parasitic nematodes; broad classification, nematode biology, physiology and ecology.

Unit III

Types of parasitism; nature of damage and general symptomatology; interaction of plant-parasitic nematodes with other organisms.

Unit IV

Plant nematode relationships, cellular responses to infection by important phytonematodes; physiological specialization among phytonematodes.

Unit V

Principles and practices of nematode management; integrated nematode management.

Unit VI

Emerging nematode problems, Importance of nematodes in international trade and quarantine.

VI. Practical

- Studies on kinds of nematodes- free-living, animal, insect and plant parasites;
- Nematode extraction from soil;
- Extraction of migratory endoparasites, staining for sedentary endoparasites;
- Examination of different life stages of important plant parasitic nematodes, their symptoms and histopathology.

VII. Suggested Reading

Dropkin VH. 1980. *An Introduction to Plant Nematology*. John Wiley & Sons, New York.
Maggenti AR. 1981. *General Nematology*. Springer-Verlag, New York.

Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed. CABI Publishing: Wallingford, UK.
Perry RN, Moens M and Starr J.L. 2009. *Root-knot nematodes*, CABI Publishing: Wallingford, UK.
Thorne G. 1961. *Principles of Nematology*. McGraw Hill, New Delhi.
Walia RK and Bajaj HK. 2003. *Text Book on Introductory Plant Nematology*. ICAR, New Delhi.
Walia RK. and Khan MR. 2018. *A Compendium of Nematode Diseases of Crop Plants,* ICAR-AICRP (Nematodes), IARI, New Delhi.

I. Course Title : Principles of Taxonomy
II. Course Code : NEMA 502
III. Credit Hours : 2+0

IV. Aim of the course

To sensitize the students on the theory and practice of classifying organisms and the rules governing the same.

V. Theory

Unit I

Introduction to history and principles of systematics and importance. Levels and functions of systematics. Identification, purpose, methods- character matrix, taxonomic keys. Descriptions- subjects of descriptions, characters, nature of characters, analogy vs homology, parallel vs convergent evolution, intra-specific variation in characters, polythetic and polymorphic taxa, sexual dimorphism.

Unit II

Classification of animals: Schools of classification- Phenetics, Cladistics and Evolutionary classification. Components of Biological Classification: Hierarchy, Rank, Category and Taxon. Species concepts, cryptic, sibling and etho-species, infra-specific categories. Introduction to numerical, biological and cytogenetical taxonomy.

Unit III

Nomenclature: Common vs Scientific names. International Code of Zoological Nomenclature, criteria for availability of names, validity of names. Categories of names under consideration of ICZN. Publications, Principles of priority, and homonymy, synonymy, type concept in zoological nomenclature. Speciation, anagenesis vs cladogenesis, allopatric, sympatric and parapatric processes.

VI. Suggested Reading

Blackwelder RE. 1967. *Taxonomy – A Text and Reference Book*. John Wiley & Sons, New York.
Kapoor VC. 1983. *Theory and Practice in Animal Taxonomy*. Oxford & IBH, New Delhi.
Mayr E. 1971. *Principles of Systematic Zoology*. Tata McGraw-Hill, New Delhi.
Quicke DLJ. 1993. Principles and Techniques of Contemporary Taxonomy. Black i.e, London.

I. Course Title : Structural and Functional Organization of Nematodes
II. Course Code : NEMA 503
III. Credit Hours : 2+1

IV. Aim of the course

Familiarization with structural organization of nematode body so as to enable the students to understand biology, physiology and classification of nematodes.

V. Theory

Unit I

Introduction and general organization of nematode body; Morphology and anatomy of nematode cuticle, hypodermis, musculature and pseudocoelom.

Unit II

Digestive system- Structural variations of stoma, oesophagus, intestine and rectum in nematodes.

Unit III

Reproductive system- Variations in female and male reproductive systems, types of reproduction, spermatogenesis and oogenesis.

Unit IV

Types and structure of excretory-secretory systems; nervous system and associated sense organs.

Unit V

Embryogenesis, Cell lineage and postembryonic development; Process of hatching and moulting.

VI. Practical

- Studies on variations in nematode shapes and sizes, morphological details of cuticle, cuticular markings and ornamentation, variations in stoma, oesophagus, rectum;
- Types and parts of female and male reproductive systems, sense organs, and excretory system.

VII. Suggested Reading

Bird AF and Bird J. 1991. *The Structure of Nematodes*. Academic Press, New York.

Chitwood BG and Chitwood MB. 1950. *An Introduction to Nematology*. Univ. Park Press, Baltimore.

Maggenti AR. 1981. *General Nematology*. Springer-Verlag, New York.

Malakhov VV. 1994. *Nematodes: Structure, Development, Classification and Phylogeny*. Smithsonian Institution Press, Washington DC.

I. Course Title : Nematode Systematics

II. Course Code : NEMA 504

III. Credit Hours : 2+1

IV. Aim of the course

Understanding concepts in nematode taxonomy, development of skills in the identification of plant parasitic nematodes up to genera and species levels.

V. Theory

Unit I

Gross morphology, principles of nematode taxonomy -levels of taxonomy, systematics vs. taxonomy, morpho-taxonomy, molecular taxonomy, identification, classification, taxonomic categories, taxonomic characters, morphometry, Zoological nomenclature, species concept and speciation (allopatric and sympatric).

Unit II

Taxonomic position of nematodes and their relationships with allied groups;

Classification and diagnoses of nematodes up to ordinal rank (Secernentea and Adenophorea)

Unit III

Taxonomy of free living nematodes

Unit IV

Classification of plant parasitic nematodes; Order Tylenchida and diagnoses of its sub-orders, super families, families and important genera; Order Aphelenchida, Dorylaimida and Triplonchida and diagnoses of their important genera.

VI. Practicals

- Collection of soil and plant samples from different habitats, processing and preservation of samples; and preparation of temporary mounts, processing of nematode specimens and permanent mounts;
- Preparation of en face view and TS of nematodes, perineal pattern of root knot nematodes and cone-top structure for cyst nematodes;
- Identification of soil and plant nematodes from nematode suspension and mounted slides;
- Camera lucida drawing of nematodes, measurement of nematodes using traditional as well as image analyzing software;
- Procedures for PCR- Taxonomy.

VII. Suggested Reading

Ahmad W and Jairajpuri MS. 2010. *Mononchida: The Predatory Soil Nematodes, Series: Nematology Monographs and Perspectives*, Volume: 7, Brill.

Geraert E. 2006. *Tylenchida*. Brill.

Hunt DJ. 1993. *Aphelenchida, Longidoridae and Trichodoridae – their Systematics and Bionomics*. CABI, Wallingford.

Jairajpuri MS and Ahmad W. 1992. *Dorylaimida: Free-Living, Predaceous and Plant-Parasitic Nematodes*, Brill.

Mai WF, Mullin PG, Lyon HH and Loeffler K. 1996. Plant-Parasitic Nematodes: A Pictorial Key to Genera, 5th ed., Cornell University Press, London.

Siddiqi MR. 2000. *Tylenchida: Parasites of Plants and Insects*. 2^{nd} Ed. CABI, Wallingford.

I. Course Title : Techniques in Nematology

II. Course Code : NEMA 505

III. Credit Hours : (1+2)

IV. Aim of the course

Understanding the principles, theoretical aspects and developing skills in nematological techniques.

V. Theory

Unit I

Principles and use of light, scanning and transmission electron microscopes, and other laboratory equipments.

Unit II

Survey and surveillance methods; collection of soil and plant samples; techniques for extraction of nematodes from soil and plant material; estimation of population densities.

Unit III

Killing, fixing, clearing and mounting nematodes; measurements, preparation of perineal patterns, vulval cones of cyst nematodes, en-face views and body section of nematodes.

Unit IV

In-vitro and *in vivo* culturing techniques of plant parasitic, bacteriophagous, mycophagus and omnivorous nematodes.

Unit V

Staining nematodes in plant tissues; microtomy for histopathological studies; collection of plant root exudates and their bioassay; preparation of plant materials for exhibition.

Unit VI

Application of molecular techniques in Nematology.

VI. Practical

- Collection of soil and plant samples;
- Extraction of nematodes from soil by Baermann funnel, sieving and decanting, elutriation and sugar centrifugal methods;
- Extraction of cysts from soil;
- Extraction of nematodes from plant material;
- Estimation of population densities;
- Staining plant material for nematodes;
- Killing and fixing nematodes, clearing nematodes by slow and Seinhorst's methods;
- Preparation of temporary and permanent mounts;
- Measurements, drawing, microphotography, special preparation of nematodes – perineal patterns, vulval cones, en-face and body sections;
- Collection of root exudates, preparation of exhibits of nematode diseased plant material, *in-vitro* culturing techniques of nematodes- callous culture, excised root and carrot disc techniques.

VII. Suggested Reading

Ayoub SM. 1981. *Plant Nematology – An Agricultural Training Aid*.

Barker KR, Carter CC and Sasser JN. 1985. *An Advanced Treatise on* Meloidogyne. Vol. II. *Methodology*. International *Meloidogyne* Project, NCSU, Raleigh. USA.

Manzanilla-Loìpez, RH and Marbaìn-Mendoza N. 2012. *Practical Plant Nematology*, Montecillo, Texcoco: Biblioteca Basica de Agricultura.

Sikora RA, Coyne D, Hallman J and Timper P. 2018. *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture.*3rd edn. CABI Publishing, England.

Southey JF. 1986. *Laboratory Methods for Work with Plant and Soil Nematodes*. HMSO, London.

Subbotin SA, Mundo-Ocampo M and Baldwin J. 2010. *Systematics of The Genus Heterodera in Systematics of Cyst Nematodes* (Nematoda: Heteroderinae), Part B, Series: Nematology Monographs and Perspectives, Volume: 8B, Brill.

Zuckerman BM, Mai WF and Harrison MB. 1985. *Plant Nematology Laboratory Manual*. Univ. of Massachusetts.

I. Course Title : Nematode Diseases of Crops

II. Course Code : NEMA 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart basic knowledge about the causal organism, nature of damage, symptoms and control of nematode diseases of agricultural and horticultural crops.

V. Theory

Diagnosis of causal organism, distribution, host range, biology and life cycle, nature of damage, symptoms, interaction with other organisms, and management of nematode diseases in different crops.

Unit I

Cereal crops- Ear-cockle and *tundu* diseases of wheat, *molya* disease of wheat and barley; rice root nematode, rice root-knot and cyst nematode problems, *ufra* and white tip diseases of rice; lesion nematodes, cyst nematodes of maize and sorghum.

Unit II

Pulses, Sugar, Fibre, Fodder and Oilseed crops- Pigeon pea cyst nematode, root knot nematode, reniform nematode, lesion, lance nematode, sugarbeet cyst and soybean cyst nematode problems.

Unit III

Vegetable crops- root-knot disease, reniform nematode, potato cyst nematode; stem and bulb nematode. Nematode problems of protected cultivation.

Unit IV

Fruit crops- root-knot nematode, reniform nematode, slow decline of citrus. Flowers- root-knot nematode, foliar nematodes, bulb nematodes, Mushroom- nematode problems.

Unit V

Plantation, medicinal and aromatic crops- burrowing nematode problem of banana, spices and condiments, root-knot and lesion nematode problems of coffee and tea, red ring disease of coconut. Forests- Pine wilt disease.

VI. Practical

- Diagnosis of causal organisms;
- Identification of different life cycle stages;
- Study of symptoms and histopathology of nematode damage in different crops, study tours for field diagnosis of nematode problems.

VII. Suggested Reading

Bhatti DS and Walia RK. 1992. *Nematode Pests of Crops*. CBS, New Delhi.

Bridge J and Starr JL. 2007. *Plant Nematodes of Agricultural Importance: A Colour Handbook*, CRC Press

Evans AAF, Trudgill DL and Webster JM. 1994. *Plant Parasitic Nematodes in Temperate Agriculture*. CABI, Wallingford.

Nickle WR. 1991. *Manual of Agricultural Nematology*. Marcel Dekker, New York.

Perry RN and Moens M. 2006. *Plant Nematology*. CABI, Wallingford.

Perry RN, Moens M and Jones JT. 2018. *Cyst Nematodes*, CABI Publishing: Wallingford, UK.

Perry RN, Moens M and Starr JL. 2009. *Root-knot nematodes*, CABI Publishing: Wallingford, UK.

Sikora R, Coyne D, Hallmann J and Timper P. 2018. *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture*, 3rd Ed., CABI, UK.

Walia RK and Khan MR. 2018. *A Compendium of Nematode Diseases of Crop Plants, ICAR-AICRP* (*Nematodes*), IARI, New Delhi.

I. Course Title : Nematode Biology and Physiology
II. Course Code : NEMA 507
III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of life cycle patterns, feeding and metabolic processes in hytonematodes which have implications in their management.

V. Theory

Unit I

Host finding and invasion, feeding, hatching, moulting; life cycle patterns in different types of nematodes.

Unit II

Types of reproduction, gametogenesis, embryogenesis and post embryogenesis.

Unit III

Chemical composition of nematodes, hydrolytic enzymes, pseudocoelom and function of transport.

Unit IV

Physiology of digestive system, intermediary metabolism.

Unit V

Osmoregulation, physiology of excretory-secretory and neuromuscular systems.

VI. Practical

- Studies on embryogenesis and post-embryogenesis, hatching, moulting, life cycle development, feeding, enzymatic assay by electrophoresis.

VII. Suggested Reading

Croll NA. 1970. *The Behaviour of Nematodes: The Activity, Senses and Responses*. Edward Arnold, London.

Croll NA and Mathews BE. 1977. *Biology of Nematodes*. Blackie, Glasgow. Lee DL. 2002. *The Biology of Nematodes*. Taylor & Francis, London.

Lee DL and Atkinson HJ. 1976. *Physiology of Nematodes*. MacMillan, London.

Perry RN and Wright DJ. 1998. *The Physiology and Biochemistry of Free- living and Plant Parasitic Nematodes*. CABI, Wallingford.

Wallace HR. 1963. *The Biology of Plant Parasitic Nematodes*. Edward Arnold, London.

I. Course Title : Nematode Ecology
II. Course Code : NEMA 508
III. Credit Hours : 2+1

IV. Aim of the course

To understand the life of plant parasitic nematodes in their environment; their survival strategies, and how to exploit these for their control.

V. Theory

Unit I

Definition and scope; components of environment; evolution of nematodes; ecological classification, prevalence, distribution and dispersal of nematodes.

Unit II

Role of nematodes in the food web; habitat and niche characteristics; community analysis and population estimation models.

Unit III

Effects of abiotic and biotic factors on nematodes.

Unit IV

Environmental extremes and nematode behaviour- aggregation, swarming, orientation, feeding and reproduction.

Unit V

Survival strategies of nematodes in adverse environment and absence of host.

Unit VI

Modeling population dynamics and relations with crop performance; ecological considerations in nematode management, data interpretation and systems simulation.

VI. Practical

- Study of nematode fauna in varied agro-ecological systems;
- Community analysis of nematode populations;
- Laboratory exercises on influence of abiotic factors on movement and hatching, green-house experiments on effect of abiotic factors on nematode populations and plant growth.

VII. Suggested Reading

Croll NA. 1970. *The Behaviour of Nematodes*: *The Activity, Senses and Responses*. Edward Arnold, London.

Croll NA and Mathews BE. 1977. *Biology of Nematodes*. Blackie, Glasgow. Lee DL. 2002. *The Biology of Nematodes*. Taylor & Francis, London.

Gaugler R and Bilgrami AL. 2004. *Nematode Behaviour*, CABI, UK.

Norton DC. 1978. *Ecology of Plant Parasitic Nematodes*. John Wiley. Poinar G. 1983. *Natural History of Nematodes*. Prentice Hall, Englewood Cliffs.

Wallace HR. 1973. *Nematode Ecology and Plant Disease*. Edward Arnold, London.

I. Course Title : Nematode Interactions with Other Organisms

II. Course Code : NEMA 509

III. Credit Hours : 2+1

IV. Aim of the course

To understand the role of nematodes in disease complexes involving fungal, bacterial, viral and other organisms.

V. Theory

Unit I

Concept of interaction and its importance in disease complexes and their management involving nematode and other organisms.

Unit II

Interaction of plant parasitic nematodes with wilt causing fungal pathogens and microfungi.

Unit III

Interaction of plant parasitic nematodes with root rot and other fungal pathogens.

Unit IV

Interaction of plant parasitic nematodes with bacterial pathogens, other nematode species and arthropods.

Unit V

Virus transmission by nematodes.

VI. Practical

- Green-house experiments to study the role of plant parasitic nematodes in wilt/ rot causing fungal and bacterial pathogens.

VII. Suggested Reading

Khan MW. 1993. *Nematode Interactions*. Chapman & Hall, New York.

Lamberti F, Taylor CE and Seinhorst JW. 1975. *Nematode Vectors of Plant Viruses*. Plenum Press, London.

Mondia JL and Timper P. 2016. Interactions of microfungi and plant parasitic nematodes. In: *Biology of Microfungi* (De-Wei-Lei Ed.). Springer Publications

Sasser JN and Jenkins WR. 1960. *Nematology*: *Fundamentals and Recent Advances with Emphasis on Plant Parasitic and Soil Forms*. Eurasia Publ. House, New Delhi.

I. Course Title : Nematode Management

II. Course Code : NEMA 510

III. Credit Hours : 2+1

IV. Aim of the course

To impart comprehensive knowledge about the principles and practices of nematode management.

V. Theory

Unit I

Concepts and history of nematode management; crop loss estimation, ecological and socio-economic aspects, cost-benefit ratios and pest risk analysis.

Unit II

Chemical methods- nematicides, their types, classification, mode of action, applicators and application methods, antidotes, and economizing nematicidal use.

Unit III

Cultural practices- crop rotations and cropping sequences, fallowing, flooding, soil solarisation, time of sowing, organic amendments of soil, bio-fumigation, antagonistic and trap crops, sanitation, etc. Physical methods- use of heat, hot water treatment and other methods of disinfestations of planting material.

Unit IV

Biological methods- concepts and terminology, use of predators and parasites as biological control agents, their mass multiplication and field use; phytotherapeutic methods – use of antagonistic plants and antinemic plant products.

Unit V

Genetic methods- plant resistance; legal methods- quarantine regulations; integrated nematode management- concepts and applications.

VI. Practical

- *In-vitro* screening of synthetic chemicals and plant products for nematicidal activity, and their application methods;
- Methods for screening of crop germplasm for resistance against nematodes, laboratory exercises on biocontrol potential of fungal, bacterial parasites, and predacious fungi and nematodes.

VII. Suggested Reading

Bhatti DS and Walia RK. 1994. *Nematode Pest Management in Crops*. CBS, New Delhi.
Brown GL. 1977. *The Nematode Destroying Fungi*. CBP, Guelph.
Brown RH and Kerry BR. 1987. *Principles and Practice of Nematode Control in Crops*. Academic Press, Sydney.
Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives. Vol. II: Nematode Management and Utilization*. CABI, Wallingford.
Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed., CABI, Wallingford, London.
Starr JL, Cook R and Bridge J. 2002. *Plant Resistance to Parasitic Nematodes.* CABI, Wallingford.
Stirling GR. 2014. *Biological Control of Plant parasitic Nematodes,* 2nd Ed., CAB International, UK.
Whitehead AG. 1997. *Plant Nematode Control*. CABI, Wallingford.

I. Course Title : Beneficial Nematodes

II. Course Code : NEMA 511

III. Credit Hours : 1+1

IV. Aim of the course

To sensitize about the use of nematodes for the biological control of insect pests of crops, and application of some nematodes as biological models and as indicators of environmental pollution.

V. Theory

Unit I

Beneficial nematode fauna – predators, parasites of insects, molluscs and other pests; Entomophilic nematodes- important groups, types of nematode- insect associations; taxonomic characteristics of nematode parasites of insects.

Unit II

Host-parasite relations and life cycle of mermithids, entaphelenchids, thelastomids, sphaerularids and tylenchids.

Unit III

Entomopathogenic nematodes- *Steinernema, Heterorhabditis, Oscheius* their morphological characteristics, taxonomic status, biology and mode of action.

Unit IV

Entomopathogenic nematodes- mass multiplication techniques, formulations, field applications and efficacy, success stories.

Unit V

Nematodes as biological models, nematodes as indicators of pollution, role of nematodes in organic matter recycling.

VI. Practical

- Isolation, identification, mass rearing and application methods of entomopathogenic nematodes.

VII. Suggested Reading

Gaugler R and Kaya HK. 1990. *Entomopathogenic Nematodes in Biological Control*. CRC Press, Boca Raton, Florida.

Gaugler R. 2002. *Entomophilic Nematology*. CABI, Wallingford. Grewal PS, Ehlars RU and Shapiro DI. 2005. *Nematodes as Biocontrol Agents*. CABI, Wallingford.

Jairajpuri MS and Khan MS. 1982. *Predatory Nematodes (Mononchida)*. Associated Publ. Co., New Delhi.

Wood WB. 1998. *The Nematode* Caenorhabditis elegans. Cold Spring Harbor Press.

Woodring JL and Kaya HK. 1988. *Steinernematid and Heterorhabditid Nematodes: A Handbook of Techniques*. Southern Coop. Bull., Ark. Ag. Ext. Sta.

Zuckerman BM. (Ed.). 1980. *Nematodes as Biological Models*. Vols. I, II. Academic Press, New York.

I. Course Title : Principles of Integrated Pest Management

II. Course Code : NEMA 512/ ENT 510

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize the students with principles of insect pest management, including concept and philosophy of IPM. Train students in computation of ETL, implementing IPM programmes.

V. Theory

Unit I

History and origin, definition and evolution of various related terminologies.

Unit II

Concept and philosophy, ecological principles, economic threshold concept, and economic consideration.

Unit III

Tools of pest management and their integration- legislative, cultural, physical and mechanical methods; pest survey and surveillance, forecasting, types of surveys including remote sensing methods, factors affecting surveys; political, social and legal implications of IPM; pest risk analysis; pesticide risk analysis; cost-benefit ratios and partial budgeting; case studies of successful IPM programmes.

VI. Practical

- Characterization of agro-ecosystems;
- Sampling methods and factors affecting sampling;
- Population estimation methods;
- Crop loss assessment- direct losses, indirect losses, potential losses, avoidable losses, unavoidable losses;
- Computation of EIL and ETL;
- Crop modeling; designing and implementing IPM system.

VII. Suggested Reading

Dhaliwal GS and Arora R. 2003. *Integrated Pest Management – Concepts and Approaches.*

Kalyani Publishers, New Delhi.
Dhaliwal GS, Ram Singh and Chhillar BS. 2006. *Essentials of Agricultural Entomology*. Kalyani Publishers, New Delhi. Flint MC and Bosch RV. 1981. *Introduction to Integrated Pest Management*. 1st Ed., Springer, New York.
Horowitz AR and Ishaaya I. 2004. *Insect Pest Management: Field and Protected Crops*. Springer, New Delhi.
Ignacimuthu SS and Jayaraj S. 2007. *Biotechnology and Insect Pest Management*. Elite Publ., New Delhi.
Metcalf RL and Luckman WH. 1982. *Introduction of Insect Pest Management*. John Wiley & Sons, New York.
Norris RF, Caswell-Chen EP and Kogan M. 2002. *Concepts in Integrated Pest Management*. Prentice Hall, New Delhi.
Pedigo RL. 2002. *Entomology and Pest Management*. 4th Ed. Prentice Hall, New Delhi.
Subramanyam B and Hagstrum DW. 1995. *Integrated Management of Insects in Stored Products*. Marcel Dekker, New York.

I. Course Title : Disease Resistance in Plants
II. Course Code : NEMA 513/ PL PATH 513
III. Credit Hours : 2+0

IV. Aim of the course

To acquaint with disease resistance mechanisms in plants.

V. Theory

Unit I

Introduction and historical development, dynamics of pathogenicity, process of infection, variability in plant pathogens, gene centres as sources of resistance, disease resistance terminology.

Unit II

Disease escape, disease tolerance, disease resistance, types of resistance, identification of physiological races of pathogens, disease progression in relation to resistance, stabilizing selection pressure in plant pathogens.

Unit III

Host defence system, morphological and anatomical resistance, preformed chemicals in host defence, post infectional chemicals in host defence, phytoalexins, hypersensitivity and its mechanisms.

Unit IV

Gene-for-gene concept, protein-for-protein and immunization basis, management of resistance genes. Strategies for gene deployment.

VI. Suggested Reading

Dallice M *et al*.1996. *Molecular Aspects of Pathogenicity and Resistance: Requirement for Signal Transduction*. APS, St Paul, Minnesota.
Deverall, B.J. 1977. *Defence Mechanisms in Plants*. Cambridge Univ. Press, Cambridge, New York.
Parker J. 2008. *Molecular Aspects of Plant Diseases Resistance*. Blackwell Publ.
Robinson RA. 1976. *Plant Pathosystems*. Springer Verlag, New York. Singh BD. 2005. *Plant Breeding – Principles and Methods*. 7th Ed. Kalyani Publishers, Ludhiana.
Van der Plank JE. 1975. *Principles of Plant Infection*. Academic Press, New York.
Van der Plank JE. 1978. *Genetic and Molecular Basis of Plant Pathogenesis*. Springer Verlag, New York.

Van der Plank JE. 1982. *Host Pathogen Interactions in Plant Disease*. Academic Press, New York.

Van der Plank JE. 1984. *Disease Resistance in Plants*. Academic Press, New York.

I. Course Title : Plant Quarantine, Biosafety and Biosecurity

II. Course Code : NEM 514/ ENT 520

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint the learners about the principles and the role of Plant Quarantine in containment of pests and diseases, plant quarantine regulations and set-up.

V. Theory

Unit I

Definition of pest, pesticides and transgenics as per Govt. notification; relative importance; quarantine – domestic and international. Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case histories of exotic pests/ diseases and their status.

Unit II

Plant protection organization in India. Acts related to registration of pesticides and transgenics. History of quarantine legislations, PQ Order 2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

Unit III

Identification of pest/ disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniques to detect pest/ pathogen infestations; VHT and other safer techniques of disinfestation/ salvaging of infected material.

Unit IV

WTO regulations; non-tariff barriers; Pest risk analysis, good laboratory practices for pesticide laboratories; pesticide industry; Sanitary and Phytosanitary measures.

VI. Suggested Reading

Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.

Rhower GG. 1991. Regulatory Plant Pest Management. In: *Handbook of Pest Management in Agriculture*. 2nd Ed. Vol. II. (Ed. David Pimental). CRC Press.

Shukla A and Veda OP. 2007. *Introduction to Plant Quarantine*. Samay Prakashan, New Delhi.

I. Course Title : IPM in Protected Cultivation

II. Course Code : NEMA 515/ PATH 521/ ENT 524

III. Credit Hours : 2+1

IV. Aim of the course

To sensitize the pest and disease scenario developing in crops raised under protected cultivation and to impart knowledge about the remedy.

V. Theory

Unit I

Characteristics of protected cultivation and tools for sustainable crop production;

outline of major biotic stresses in protected cultivation including: fungi, bacteria, virus, nematode, insects and mites.

Unit II

Sampling and monitoring pests and diseases; epidemiology and damage relationships; loss assessment; population dynamics of biotic stress agents; factors responsible for severity of pests and diseases.

Unit III

Host plant resistance to pathogens and insects; management strategies for protected cultivation: disinfestation of soil and growth media; preventive, scouting and early detection; and curative measures: biological control of sap sucking pests, leaf miners; soil- and air-borne pathogens; pesticides selectivity, applications and resistance management; buzz pollination.

VI. Practical

- Visit to familiarize with pest and disease situations developing in protected cultivation;
- Symptomatology and damages; identification of the causes; estimation of population densities; management tactics/ approaches and recommendations; production and commercialization of biological agents.

VII. Learning outcome

Students are expected to be well versed with the crop pest and disease problems associated with protected cultivation and their management.

VIII. Suggested Reading

Gullino ML, Albajes, R and Nicot P. 2019. *Integrated Pest and Disease Management in Greenhouse Crops*. Ed. 2nd, Springer, New York.

Rathee *et al*. 2018. Integrated Pest Management under Protected Cultivation—A Review. *Journal of Entomology and Zoology Studies*, 6 (2): 1201–1208.

IX. List of Journals

- *Annals of Applied Nematology* – Society of Nematologists, USA
- *Current Nematology* – Bioved Research Society, Allahabad, India
- *Egyptian Journal of Agronematology* – Egyptian Society of Agricultural Nematology
- *Indian Journal of Nematology* – Nematological Society of India
- International Journal of Nematology – Afro-Asian Society of Nematologists, Luton
- *Japanese Journal of Nematology* – Japanese Nematological Society
- *Journal of Nematology* – Society of Nematologists, USA
- *Journal of Nematode Morphology and Systematics* –Jaen, Universidad de Jaen
- *Nematologia Brasiliera* – Brazilian Nematological Society
- *Nematologia Mediterranea* – Istituto per la Protezione delle Plante (IPP) – Sect. of Bari of the CNR, Italy
- *Nematology* – EJ Brill Academic Publishers, UK
- *Nematropica* – Organization of Nematologists of Tropical America
- *Pakistan Journal of Nematology* – Pakistan Society of Nematologists
- *Russian Journal of Nematology* – Russian Society of Nematologists

e-Resources

http://www.nematologists.org/ (The Society of Nematologists)
http://nematology.ucdavis.edu/ (Deptt. of Nematology, Univ. of California, Davis)
http://www.ifns.org/ (International Federation of Nematology Societies)

http://www.inaav.ba.cnr.it/nemmed.html (Nematologia Mediterranea)
http://nematode.unl.edu/Nemajob.htm (Nematology Employment Bulletin Board)
http://nematode.unl.edu/ (University of Nebraska – Lincoln Nematology)
http://nematode.unl.edu/wormsite.htm (Links to Other Nematology Resources)
http://nematode.unl.edu/SON/jon.htm (Journal of Nematology)
http://www.nematology.ucr.edu/ (Deptt. of Nematology, Univ. of California, Riverside)
http://entnemdept.ifas.ufl.edu/ (Univ. of Florida, Entomology and Nematology Dept.)
http://www.brill.nl/m_catalogue_sub6_id8548.htm (Nematology – journal)
http://www.ars.usda.gov/main/site_main.htm?modecode=12752900 (Nematology Lab., USDA)
http://flnem.ifas.ufl.edu/history/nem_history.htm (Nematology history)
http://www.nematology.ugent.be/ (Nematology Unit, Ghent University)
http://www.entm.purdue.edu/nematology/ (The Purdue Nematology Lab.)
http://www.bspp.org.uk/ppigb/nematolo.htm#a-z (Links to Nematology labs)
http://www.nem.wur.nl/UK/ (Laboratory of Nematology, Wageningen Univ.)
http://onta.ifas.ufl.edu/ (The Organization of Nematologists of Tropical America)
http://www.openj-gate.org/Articlelist.asp?Source=1&Journal_ID=103267. (Nematology Newsletter)
http://nematology.umd.edu/nematology.html (Plant Nematology Laboratory, Maryland)
http://www.biology.leeds.ac.uk/nem/ (Plant Nematology Lab., University of Leeds)
http://www.plantpath.iastate.edu/dept/labs/tylka/ (Iowa State University, Nematology Lab)
http://nematologists.org.au/newsletters.html (Australasian Association of Nematologists)
http://soilplantlab.missouri.edu/nematode/ (Plant Nematology Laboratory, Missouri)
http://www.eumaine.ugent.be/ (European Master of Science in Nematology)
http://www.jstage.jst.go.jp/browse/jjn (The Japanese Journal of Nematology)

Suggested Broad Topics for Master's and Doctoral Research

- Identification of key nematode pests emerging in regional agro-ecosystems
- Development of molecular diagnostic tools of phytonematodes
- Nematode problems of peri-urban and protected agriculture systems, and their management
- Role of nematodes in organic matter recycling
- Modelling nematode populations for disease forecasting and predicting yield losses
- Nematodes as indicators of environmental pollution
- Identification of cost effective nematode-suppressive cropping systems for specific agro-ecosystems
- Isolation, identification and characterization of phytochemicals for nematoxicity
- Disinfection of nematode-infected planting material through eco-friendly sanitary methods
- Characterization of molecular markers and genes governing resistance to key nematode pests
- Management of nematodes with antagonistic bacteria
- Bionomics of potential bio-control agents and their field efficacy
- Devising non-chemical methods of nematode management in mushroom cultivation
- Development of nematode management modules for IPM systems
- Field efficacy and formulation of entomopathogenic nematodes against foliar and soil-borne insect pests of crops
- Study of disease complex involving nematodes and other plant pathogens.
- Nematode suppressive rhizospheric microorganisms.
- Nematode suppressive endophytes.
- Management of nematodes using RNAi
- Factors related to entomopathogenic nematode- bacterium symbionts
- Management of root knot nematodes in protected cultivation system
- Assessment of nematode damage and yield losses in organic farming system

Course Title with Credit Load
Ph.D. in Nematology

Course Code	Course Title	Credit Hours
NEMA 601**	Nematode Phylogeny and Systematics	2+1
NEMA 602**	Nematode Disease Development and Host Resistance	2+1
NEMA 603**	Advances in Nematode Management	2+1
NEMA 604**	Physiological and Molecular Nematology	2+1
NEMA 605/ PL PATH 606@	Plant Biosecurity and Biosafety	2+0
NEMA 691	Doctoral Seminar I	1+0
NEMA 692	Doctoral Seminar II	1+0
NEMA 699	Doctoral Research	75

**Core Courses for Doctoral Programme; @Cross-listed with Plant Pathology; $Cross-listed with Entomology

Course Contents
Ph.D. in Nematology

I. Course Title : Nematode Phylogeny and Systematics
II. Course Code : NEMA 601
III. Credit Hours : 2+1

IV. Aim of the course

Concepts in Systematics, understanding nematode diversity, evaluation and analysis of taxonomic characters for inferring interrelationships among nematode groups, modern methods and tools for identification of nematodes, and phylogenetic analysis.

V. Theory

Unit I

Phylogenetic systematics – Evolutionary systematics, Cladistics, phylogenetic trends (morphological) and molecular phylogenetic framework for the phylum Nematoda, phylogenomics

Unit II

Taxonomic characters, numerical taxonomy, morphometry, variations, statistics in taxonomic descriptions, description of new species, preparation of illustrations, keys and compendia for nematode species.

Unit III

Identification of common species of root knot nematodes by esterase phenotypes and race/ pathotypes of root knot/ cyst/ reniform nematodes by differential host tests.

Unit IV

Recent advances in nematode identification- molecular, biochemical, immunodiagnostic, molecular characterization and DNA finger-printing techniques.

VI. Practical

- Detailed studies of morphological structures and identification of plant parasitic nematodes up to species level;
- Preparation of compendia and keys;
- Drawing and measurements using camera lucida and computer software;
- Procedures for identification of species/ races of root-knot/ cyst/ reniform nematodes.
- Isozyme analysis for identification of common species of root knot nematodes. rDNA-RFLP for diagnosis of nematode species;
- Sequence analysis, alignment, phylogenetic analysis, preparation of phylogenetic tree and interpretation.

VII. Suggested Reading

Andraìssy I. 1976. *Evolution as a basis for the systematization of nematodes*. Pitman Publishing Ltd, London.

Blackwelder RE. 1967. *Taxonomy – A Text and Reference Book*. John Wiley & Sons, New York.

Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives. Vol. I. Nematode Morphology, Physiology and Ecology*. CABI, Wallingford.
Fortuner R. 1988. *Nematode Identification and Expert System Technology*. NATO Science Series A: Springer US.
Geraert E. 2006. *Nematology Monographs and Perspectives*. Vol. IV. EJ. Brill.
Kapoor VC. 1983. *Theory and Practice in Animal Taxonomy*. Oxford & IBH, New Delhi.
Mayr E. 1969. *Principles of Systematic Zoology*. Tata McGraw-Hill, New Delhi.
Quicke DLJ. 1993. *Principles and Techniques of Contemporary Taxonomy*. Blackie, London.
Stone AR, Platt HM and Khalil LF. 1983. *Concepts in Nematode Systematics, the Systematics Association Special Volume* No. 22, Academic Press, London and NY.

I. Course Title : Nematode Disease Development and Host Resistance
II. Course Code : NEMA 602
III. Credit Hours : 2+1

IV. Aim of the course

To update knowledge on the recent research trends in the field of plant nematode relationships at genetic and molecular level.

V. Theory

Unit I

Mechanisms of pathogenesis, cytological and biochemical changes induced by nematode feeding.

Unit II

Plant defense systems, role of phytoalexins, etc. against major plant parasitic nematodes.

Unit III

Genetic basis of plant resistance to nematodes and identification of resistance genes against economically important nematodes.

Unit IV

Application of biotechnological methods in the development of nematode resistant crop cultivars; resistance markers; incorporation of resistance by conventional breeding and transgenic approaches.

Unit V

Influence of microorganisms on plant nematode interactions.

VI. Practical

- Microtomy for study of histopathological changes induced by important nematodes, screening techniques for assessment of resistance in crop germplasm against nematodes.

VII. Suggested Reading

Barker KR, Pederson GA and Windham GL. 1998. *Plant and Nematode Interactions*. CABI, Wallingford.
Fenoll C, Grundler FMW and Ohl SA. 1997. *Cellular and Molecular aspects of Plant-Nematode Relationships*. Kluwer Academic Press, Dordrecht.
Lamberti F, Giorgi C and Bird D. 1994. *Advances in Molecular Plant Nematology*. Plenum Press.

I. Course Title : Advances in Nematode Management

II. Course Code : NEMA 603

III. Credit Hours : 2+1

IV. Aim of the course

To keep abreast ith latest developments and trends in nematode management.

V. Theory

Unit I

Isolation, identification, host specificity, mode of action, culturing and field application potential of promising bio-control agents- predacious and parasitic fungi; nematoxic fungal culture filtrates.

Unit II

Isolation, identification, host specificity, mode of action, culturing and field application potential of promising bio-control agents- parasitic and nematode antagonistic bacteria; predacious mites and predacious nematodes.

Unit III

Mass culturing, formulation, quality control, bio-safety and registration protocols of bio-control agents.

Unit IV

Phytoalexins, allelochemicals, phytotherapeutic substances, novel nematicides, deployment of resistant varieties and non-host crops in nematode suppressive cropping systems, emergence of resistance breaking biotypes, recent regulatory provisions and methods, quarantine and disinfection.

Unit V

Nematode management modules for integrated pest and disease management in cropping systems. Nematode management options and approaches for organic farming, precision farming and protected cultivation system. Application of GIS and GPS technology for surveillance and management.

VI. Practical

- Green-house experiments on the efficacy of fungal and bacterial bio-control agents, botanicals.

VII. Suggested Reading

Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives Vol. II. Nematode Management and Utilization.* CABI, Wallingford.

Jana BL. 2008. *Precision Farming*. Research Books and Periodicals Pvt. Ltd., Delhi.

Lillesend TW, Kiefer RW and Chipman JW. 1979. *Remote Sensing and Image Interpretation*. John Wiley & Sons, New York.

Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed., CABI, Wallingford, London.

Poinar GO Jr and Jansson H-B. 1988. *Diseases of Nematodes*. Vols. I, II. CRC Press, Boca Raton, Florida. Scientific Publ., Jodhpur.

Starr JR, Cook R and Bridge J. 2002. *Plant Resistance to Parasitic Nematodes*. CABI, Wallingford.

Stirling GR. 2014. *Biological Control of Plant parasitic Nematodes,* 2nd Ed., CAB International, UK

Tarafdar JC, Priputhi KP and Kumar M. 2007. *Organic Agriculture*. Upadhyaya RK, Walia RK and Dubey OP. 2004. *IPM Systems in Agriculture. Vol. IX. Phytonematology*. Aditya Books, New Delhi.

I. Course Title : Physiological and Molecular Nematology

II. Course Code : NEMA 604

III. Credit Hours : 2+1

IV. Aim of the course

Appraisal on the application of modern biotechnological tools in Nematology.

V. Theory

Unit I

Cell biology- Structural and functional aspects; genetics and evolution in plant parasitism in nematodes.

Unit II

Caenorhabditis elegans- a model system for gerontology, cytogenetics, physiology, nutritional, toxicological and pharmacological studies; *Heterodera glycines* as a model for biology, proteomic and genomic studies.

Unit III

Chemoreception, neurobiology, and biochemical basis of communication in nematodes, molecular basis of host recognition, Nematode-Associated Molecular Patterns (NAMPs), molecular pathways of plant-nematode interaction.

Unit IV

Biochemical, genetical and molecular basis of plant nematode interaction; histopathological, cellular and molecular changes in host feeding cells, resistance genes, genome editing, sequencing of genome, Transcriptome and Proteome analysis of plant parasitic nematodes, RNAi technology,

Unit V

Biochemical and molecular basis of survival strategies in nematodes, molecular mechanism of host resistance against plant parasitic nematodes, molecular and novel approaches for nematode management.

VI. Practical

- Isolation and quantification of proteins from nematode juveniles and eggs;
- Molecular weight determination of nematode protein;
- Buffer preparation for molecular techniques, PCR, â-esterase polymorphism in root-knot nematode;
- Nematode DNA isolation from juveniles and eggs;
- RFLP of nematode DNA;
- Nematode DNA amplification using PCR for nematode identification, RNAi technology.

VII. Suggested Reading

Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives. Vol. I. Nematode Morphology, Physiology and Ecology*. CABI, Wallingford.

Fenoll C, Grundler FMW and Ohl SA. 1997. *Cellular and Molecular aspects of Plant-Nematode Relationships*. Kluwer Academic Publ., Dordrecht.

Gommers EJ and Maas PW. 1992. *Nematology from Molecule to Ecosystem*. European Soc. of Nematologists.

Lamberti F, Giorgi C and Bird D. 1994. *Advances in Molecular Plant Nematology*. Plenum Press.

Perry RN and Wright DJ. 1998. *The Physiology and Biochemistry of Free- living and Plant Parasitic Nematodes*. CABI, London.

Riddle DL. 1997. *C. elegans II*. Cold Spring Harbor Press.

Wood WB. 1988. *The Nematode Caenorhabditis elegans*. Cold Spring Harbor Press, US

Zuckerman BM. 1980. *Nematodes as Biological Models*. Vols. I, II. Academic Press, New York.

I. Course Title : Plant Biosecurity and Biosafety

II. Course Code : NEMA 605/ PL PATH 606

III. Credit Hours : 2+0

IV. Aim of the course

To facilitate deeper understanding of plant biosecurity and biosafety issues in agriculture.

V. Theory

Unit I

History of biosecurity, concept of biosecurity, components of biosecurity, Quarantine, Invasive Alien Species, biowarfare, emerging/ resurgence of pests and diseases.

Unit II

National Regulatory Mechanism and International Agreements/ Conventions, viz., Agreement on Application of Sanitary and Phytosanitary (SPS) Measures/ World Trade Organization (WTO), Convention on Biological Diversity (CBD), International Standards for Phytosanitary Measures, pest risk analysis, risk assessment models, pest information system, early warning and forecasting system, use of Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/ disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity.

Unit III

Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, issues related to release of genetically modified crops.

VI. Suggested Reading

Biosecurity: A Comprehensive Action Plan.

Biosecurity Australia.

Biosecurity for Agriculture and Food Production.

FAO Biosecurity Toolkit 2008.

Grotto Andrew J and Jonathan B Tucker. 2006. Biosecurity Guidance.

Khetarpal RK and Kavita Gupta. 2006. Plant Biosecurity in India – Status and Strategy. Asian Biotechnology and Development Review 9(2): 3963.

Randhawa GJ, Khetarpal RK, Tyagi RK and Dhillon. BS (Eds.). 2001. Transgenic Crops and Biosafety Concerns. NBPGR, New Delhi.

e-Resources

http://www.inspection.gc.ca/english/anima/heasan/fad/biosecure.sht ml

www.fao.org/docrep/010/a1140e/a1140e00.htm Laboratory

http://www.who.int/csr/resources/publications/biosafety/WHO_CD S_EPR_2006.pdf

http://www.americanprogress.org/kf/biosecurity_ a_comprehensive_ action_plan.pdf

www.biosecurity.govt.nz DEFRA. www.defra.gov.uk/animalh/diseases/control/biosecurity/index.htm www.daff.gov.au/ba;www.affa.gov.au/biosecurityaustralia Biosecurity New Zealand. http://www.fao.org/biosecurity/ CFIA.

VII. List of Journals

- *Annals of Applied Nematology* – Society of Nematologists, USA
- *Current Nematology* – Bioved Research Society, Allahabad, India
- *Egyptian Journal of Agronematology* – Egyptian Society of Agricultural Nematology
- *Indian Journal of Nematology* – Nematological Society of India
- International Journal of Nematology – Afro-Asian Society of Nematologists, Luton
- *Japanese Journal of Nematology* – Japanese Nematological Society
- *Journal of Nematology* – Society of Nematologists, USA
- *Journal of Nematode Morphology and Systematics* –Jaen, Universidad de Jaen
- *Nematologia Brasiliera* – Brazilian Nematological Society
- *Nematologia Mediterranea* – Istituto per la Protezione delle Plante (IPP) – Sect. of Bari of the CNR, Italy
- *Nematology* – EJ Brill Academic Publishers, UK
- *Nematropica* – Organization of Nematologists of Tropical America
- *Pakistan Journal of Nematology* – Pakistan Society of Nematologists
- *Russian Journal of Nematology* – Russian Society of Nematologists

e-Resources

http://www.nematologists.org/ (The Society of Nematologists)
http://nematology.ucdavis.edu/ (Deptt. of Nematology, Univ. of California, Davis)
http://www.ifns.org/ (International Federation of Nematology Societies)
http://www.inaav.ba.cnr.it/nemmed.html (Nematologia Mediterranea)
http://nematode.unl.edu/Nemajob.htm (Nematology Employment Bulletin Board)
http://nematode.unl.edu/ (University of Nebraska – Lincoln Nematology)
http://nematode.unl.edu/wormsite.htm (Links to Other Nematology Resources)
http://nematode.unl.edu/SON/jon.htm (Journal of Nematology)
http://www.nematology.ucr.edu/ (Deptt. of Nematology, Univ. of California, Riverside)
http://entnemdept.ifas.ufl.edu/ (Univ. of Florida, Entomology and Nematology Dept.)
http://www.brill.nl/m_catalogue_sub6_id8548.htm (Nematology – journal)
http://www.ars.usda.gov/main/site_main.htm?modecode=12752900 (Nematology Lab., USDA)
http://flnem.ifas.ufl.edu/history/nem_history.htm (Nematology history)
http://www.nematology.ugent.be/ (Nematology Unit, Ghent University)
http://www.entm.purdue.edu/nematology/ (The Purdue Nematology Lab.)
http://www.bspp.org.uk/ppigb/nematolo.htm#a-z (Links to Nematology labs)
http://www.nem.wur.nl/UK/ (Laboratory of Nematology, Wageningen Univ.)
http://onta.ifas.ufl.edu/ (The Organization of Nematologists of Tropical America)
http://www.openj-gate.org/Articlelist.asp?Source=1&Journal_ID=103267. (Nematology Newsletter)
http://nematology.umd.edu/nematology.html (Plant Nematology Laboratory, Maryland)
http://www.biology.leeds.ac.uk/nem/ (Plant Nematology Lab., University of Leeds)
http://www.plantpath.iastate.edu/dept/labs/tylka/ (Iowa State University, Nematology Lab)
http://nematologists.org.au/newsletters.html (Australasian Association of Nematologists)
http://soilplantlab.missouri.edu/nematode/ (Plant Nematology Laboratory, Missouri)
http://www.eumaine.ugent.be/ (European Master of Science in Nematology)
http://www.jstage.jst.go.jp/browse/jjn (The Japanese Journal of Nematology)

Suggested Broad Topics for Master's and Doctoral Research

- Identification of key nematode pests emerging in regional agro-ecosystems
- Development of molecular diagnostic tools of phytonematodes
- Nematode problems of peri-urban and protected agriculture systems, and their management
- Role of nematodes in organic matter recycling
- Modelling nematode populations for disease forecasting and predicting yield losses

- Nematodes as indicators of environmental pollution
- Identification of cost effective nematode-suppressive cropping systems for specific agro-ecosystems
- Isolation, identification and characterization of phytochemicals for nematoxicity
- Disinfection of nematode-infected planting material through eco-friendly sanitary methods
- Characterization of molecular markers and genes governing resistance to key nematode pests
- Management of nematodes with antagonistic bacteria
- Bionomics of potential bio-control agents and their field efficacy
- Devising non-chemical methods of nematode management in mushroom cultivation
- Development of nematode management modules for IPM systems
- Field efficacy and formulation of entomopathogenic nematodes against foliar and soil-borne insect pests of crops
- Study of disease complex involving nematodes and other plant pathogens.
- Nematode suppressive rhizospheric microorganisms.
- Nematode suppressive endophytes.
- Management of nematodes using RNAi
- Factors related to entomopathogenic nematode- bacterium symbionts
- Management of root knot nematodes in protected cultivation system
- Assessment of nematode damage and yield losses in organic farming system

ANNEXURE I

List of BSMA Committee Members for Plant Protection

(Entomology/ Nematology/ Plant Pathology)

Name	Address	Specialization
Dr S Lingaraju Emeritus Professor	University of Agricultural Sciences, Residential address: No. 32, 'Vruddhi' Siddarameswar Colony Ranichannamimanagar Dharwad-580 001 Karnataka lingaraju_s@rediffmail.com; lingarajus@uasd.in Mob.: 09886560055	Chairman
Dr AK Bhaumick Head	Department of Entomology, Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur, Madhya Pradesh dr.bhowmick@gmail.com Mob.: 09424313301	Convener
Dr Ataur Rahman Professor and Head	Department of Entomology Faculty of Agriculture Assam Agricultural University Jorhat-785 013 Assam rahmanataur86@yahoo.com Mob.: 09435489475	Member
Dr R Swaminathan Former Dean	Department of Entomology Maharana Pratap University of Agriculture and Technology Udaipur-313 001 Rajasthan House No. 5, Shiv Badi, kharol Colony Fatehpura, Udaipur-313 004 (Rajasthan) udaiswami57@gmail.com; Mob.: 09950964908	Member
Dr BA Patel Professor and Head	Department of Nematology Anand Agricultural University Anand, Gujarat bapatel@aau.in; Mob.: 09916063028	Member
Dr KT Rangaswamy	Department of Plant Pathology University of Agricultural Sciences Bengaluru, Karnataka ktr_uasb@rediffmail.com; Mob.: 09916063028	Member
Dr MS Joshi	Department of Plant Pathology DBSKVV, Dapoli, Maharashtra majoshi1234@rediffmail.com; Mob.: 09420639320	Member

Restructured and Revised
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Vol. 1

Horticultural Sciences

– Fruit Science (FSC)
– Vegetable Sciences (VSC)
– Floriculture and Landscaping (FLS)
– Plantation, Spices, Medicinal and Aromatic Crops (PSMA)
– Post Harvest Management (PHM)

Contents

Acknowledgements

We place on record our profound gratitude to Dr Trilochan Mohapatra, the Hon. Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG education in Horticulture. Our heartfelt thanks are due to Dr Narendra Singh Rathore, Former DDG (Education), ICAR and Dr Arvind Kumar, Hon. Vice Chancellor, RLBCAU, Jhansi and Chairman, National Core Committee for providing support and guidance in this important academic venture. Dr G. Venkateswarlu, ADG (EQR) and Dr K.L. Khurana, Principal Scientist, Education Division, ICAR requires special mention for their support and guidance. The support of Prof. Rajesh Bhalla, Hon'ble Vice Chancellor, VSCGUUHF, Bharsar and Prof. B.P. Nautiyal, Professor, VSCGUUHF, Bharsar and Local Nodal Officer of 1st BSMA-Horticulture is of immense value to begin the task through organizing the 1st meeting in a well planned way. The experience shared by Dr S.K. Gupta, Dean, College of Forestry, Ranichauri about the BSMA-Forestry workshop provided good insight about the task ahead.

We express our heartfelt gratitude to Dr D.D. Patra, Hon'ble Vice Chancellor; Prof. P. Hazra, Professor of Vegetable Science and Dean Post Graduate Studies and their team, BCKV, Kalyani for hosting the national level workshop wherein 33 esteemed delegates representing 22 SAUs/ SHUs/ DUs/ ICAR institutes; 5 Deans and Directors of BCKV, 4 University HoDs and 9 senior horticulture faculty from BCKV deliberated on the syllabi revision for three days. Committee is much obliged to Dr Rintu Banerjee, Sr. Academician, IIT, Kharagpur and Dr A.K. Chakrabarthy, Former Principal Scientist, Vegetable Crops, IARI, New Delhi for being accepted our invitation and participated in the deliberations of the workshop at BCKV, Kalyani.

Our sincere thanks are due to Dr A.K. Singh, Hon. Director IARI for hosting the 2nd meeting of BSMA Horticulture. The efforts of Dr S.K. Singh, Division-Head, and Dr V.B. Patel, Sr. Scientist, Division of Fruits and Horticulture Technology are gratefully acknowledged for arranging the meeting in befitting manner. The active participation of Horticulture fraternity of IARI, New Delhi in the meeting deliberations and discussions, has been gratefully acknowledged.

The expertise support and gesture extended by Dr K.L. Chadha, Former National Professor, Former DDG (Hort.) and Dr S.K. Pal, Former Director, NRC Pomegranate, Solapur for being accepted our invitation and added thoughts and strength to the 2nd meeting proceedings at IARI, New Delhi.

All support extended by Dr K.M. Indiresh, Hon. Vice Chancellor, University of Horticultural Sciences, Bagalkot for providing administrative and financial support in completing the task is highly appreciated and acknowledged.

Our thanks are due to all Hon. Vice Chancellors of State Agricultural and or Horticultural Universities in their support and readiness to nominate the senior horticulture faculty from their universities/ institutes to the workshop at BCKV, Kalyani.

The technical support extended by the College level committee lead by Dr Vishnuvardhan, Dean along with Dr G.K. Seetharamu, Assoc. Professor (FLA); Dr P.M. Munikrishnappa, Assoc. Professor (FLA); Dr H.C. Krishna, Asst. Professor (PHT);

Dr B.N. Marutiprasad, Asst. Professor (PSMA); Dr G.K. Ramegowda, Asst. Professor (Ag. Ent.); Dr G.K. Sadananda, Asst. Professor (PHT); Dr Jyothi Kattegoudar, Asst. Professor (VSC) and Mr Sreekanth, H. S., Asst. Professor (FSC) for processing this document and the typographic assistance by Mr Srikanth, H.C., is greatly acknowledged. The finance and accounts support extended by Mrs Bharathi M. Bongale, Assistant Comptroller; Mr Ajith Kumar, K.B., Sr. Assistant and Mr Girish M. Hebbal, Asst. Cum Computer Operator for timely arrangement and settlement of accounts.Above all, but not the least the cooperation and support extended to the convener of the committee by Dr R.C. Jagadeesha, Dean and Dr Vishnuvardhan, Former Dean, College of Horticulture, UHSB Campus, GKVK, Bengaluru is highly acknowledged.

Chairman, Convener and Members
BSMA-Horticulture Sciences-2019

General Introduction

Horticulture plays a pivotal role in the food and livelihood security of India. Though horticulture crops occupy only 8.5 per cent of areable land, they contribute 25.5 per cent of the Agriculture GDP. Plantation crops especially tea, coffee and rubber crops just occupying 0.95 per cent to of cropped area have stake of 15.1 per cent of the total expert earnings of agricultural produce. Therefore, the country has considered horticultural and plantation sector as the growth engine of Agricultural economy. It is important to mention here that the horticultural crop production in the country surpassed food production for the first time during 2013–14. The trend has been continuing and production for the year 2017–18 has been in order of 321 million tones. Over last decades, the area under horticultural crops grew by about 3 per cent per annum with increase in annual production by 5.4 per cent and the share of horticulture output in agriculture being more than 33 per cent.

Coming to the genesis and development of horticultural education in the country it dates back to mid 1930's where horticulture was considered as a part of Economic Botany in the College of Agriculture, Pune. It became independent department, subsequently, in several SAU's. At present, the discipline of horticulture has been further bifurcated upto five departments in may agri-horticultural universities in the country.

The BSMA constituted by the ICAR vide OO. No.F.No.13(1)/2007-EQR dated January 14, 2008 under Chairmanship of Dr K.V. Peter, Former Vice-Chancellor, formulated the common PG Syllabus for Horticulture discipline for the first time and recommended for implementation of the same uniformly throughout the country. The document was published by the ICAR during April 2009. The said committee, considered four discipline in horticulture science, viz., Fruit Science, Vegetable Science, Floriculture and Landscape Architecture and Plantation, Spices, Medicinal and Aromatic Crops, instead of one composite discipline, viz., Horticulture.

The ICAR in its O.O.F.No.7/6/2017 EQR dt: 04.04.2018 has constituted 19 BSMA Committees based on the National Core Group recommendations to look into various issues related to PG Programmes with the following terms of reference.

1. Development of Academic Regulations for Master and Ph.D. program
2. Refining names and curricula of Master's and Ph.D. disciplines for uniformity.
3. Revision of syllabi for courses and Master's and Ph.D. degree programmes.

Overall Recommendations

1. It was decided to reintroduce the degree programme in M.Sc. (Hort.)/ Ph.D. (Hort.) in Post-harvest Management.
2. It was decided to adopt common Academic regulation proposed by the Rani Laxmi Bai Central Agricultural University, Jhansi, Madhya Pradesh as presented and discussed during review meeting during 23–24, April 2019, NASC, New Delhi.
3. It was recommended to have degree nomenclatures in Postgraduate programmes of Horticulture are as follows.
   (a) M.Sc. (Hort.)/ Ph.D. (Hort.) Vegetable Science
   (b) M.Sc. (Hort.)/ Ph.D. (Hort.) Fruit Science
   (c) M.Sc. (Hort.)/ Ph.D. (Hort.) Floriculture and Landscaping

(d) M.Sc. (Hort.)/ Ph.D. (Hort.) Plantation, Spices, Medicinal and Aromatic Crops
(e) M.Sc. (Hort.)/ Ph.D. (Hort.) Post-harvest Management

4. It was also recommended to propose names of department on the same lines to bring the uniformity among SAU's, CAU's, Deemed Universities, etc.
5. It was decided to include common compulsory courses as finalized by other BSMA Committees for those courses which are common across disciplines.

Discipline-wise Restructured Syllabi

The course structure and minimum credit requirement as evolved through a series of meetings and workshops of BSMA-Horticultral Scienes and Review meetings by NCG are as follows:

	Masters' Programme	Doctoral Programme
(i) **Course work**		
Major Courses	20	12
Minor Courses	08	06
Supporting Course(s)	06	05
Common compulsory courses	05	–
Seminar	01	02
(ii) **Comprehensive Exam**	–	Non-credit course
(iii) **Thesis/ Research**	30	75
Total	**70**	**100**

Major Courses: The courses in the Department/ Discipline in which a student takes admission.

Minor Courses: The courses closely related to a student's major discipline (Horticultural Sciences).

Supporting Courses: The courses not related to the major discipline. It could be any course considered relevant for student's research work or necessary for building his overall competence.

Common Compulsory Courses: These following courses will be offered preferably as e-courses for all students undergoing Master's degree programme. The Courses, PGS-503 and PGS-505 are already in the form of e-courses.

Common compulsory courses

Course Code	Course Title	Credit Hours
PGS-501	Library and Information Services	0+1
PGS-502	Technical Writing and Communications Skills	0+1
PGS-503	Intellectual Property and its Management in Agriculture	1+0
PGS-504	Basic Concepts in Laboratory Techniques	0+1
PGS-505	Agricultural Research, Research Ethics and Rural Development Programmes	1+0

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Horticultural Sciences
– Fruit Science

Preamble

(Fruit Science)

India is one of the top ranking fruit producing countries in the world. It is evident from current estimates that India is producing to the tune of 100 million metric tonnes on annual basis with average productivity of 14-15 tonnes per hectare. Diverse and peculiar agro-ecological conditions prevalent in the country lays down a suitable platform to grow wide range of tropical, subtropical and temperate fruits including nuts. Given the statistics, India is the largest producer of fruits like mango, banana, papaya and pomegranate achieving highest productivity in grape, banana and papaya on the global scenario. Several fruits like mango, banana, grapes, etc. are being exported besides several others have untapped export potential to earn foreign exchange. On the whole, horticulture contributes about 30 per cent to GDP of agriculture, with major contributions coming from cultivation and processing of fruits and nuts. It is worth mentioning that fruit production occupies a special role in today's multi-faceted agriculture.

Per capita consumption of fruits have increased significantly owing to consumer's awareness for healthy foods rich in vitamins, minerals and antioxidants coupled with enhanced levels of productivity leading to increased availability. Fruit production has witnessed tremendous developments owing to systematic research efforts in the past few decades. Notable examples are making available quality planting material including rootstocks through genetic improvement and efficient propagation protocols; judicious and integrated use of water and nutrients through micro-irrigation approaches; biotic and abiotic stress management practices; high density planting systems; crop regulation and pre- and post harvest management.

The above mentioned wide ranging advancements in the field of fruit science necessitate their precise inclusion in the course curricula for delivering and assuring quality education in an updated manner. This specifically aims to develop an especially trained cadre of human resource equipped with holistic and updated knowledge in fruit science. Thus, the various courses so developed constitute the State-of-Art framework of modern practices in fruit production and orchard management. The course design lays requisite emphasis on skill development in addition to addressing the educational requirements of the post-graduate students *vis-a-vis* latest know-how. Course contents have been framed to encompass various related fields like physiology, biochemistry, genetic and molecular biology to draw better insight and understanding into the different mechanisms underlying sustainable fruit production systems.

In short, course restructuring can be viewed as a comprehensive package drawing deeper insight into cultural and management practices extending from superior cultivars/ rootstocks, planting systems, propagation methods, training and pruning, orchard floor management, plant protection measures, crop regulation, maturation and harvesting. The existing courses have been redesigned to include the technological interventions, molecular approaches and hi-tech innovations made in the last decade or so. Courses have been added on Systematics, Nutrition, Research Ethics and Methodologies, Smart Fruit Production to broaden the student's reach of understanding of principles and modern trends in fruit growing.

Course Title with Credit Load
M.Sc. (Hort.) in Fruit Science

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
FSC 501*	Tropical Fruit Production	2+1
FSC 502*	Sub-Tropical and Temperate Fruit Production	2+1
FSC 503*	Propagation and Nursery Management of Fruit Crops	2+1
FSC 504*	Breeding of Fruit Crops	2+1
FSC 505	Systematics of Fruit Crops	2+1
FSC 506	Canopy Management in Fruit Crops	1+1
FSC 507	Growth and Development of Fruit Crops	2+1
FSC 508	Nutrition of Fruit Crops	2+1
FSC 509	Biotechnology of Fruit Crops	2+1
FSC 510	Organic Fruit Culture	2+1
FSC 511	Export Oriented Fruit Production	2+1
FSC 512	Climate Change and Fruit Crops	1+0
FSC 513	Minor Fruit Production	2+1
	Minor Courses	**08**
	Supporting Courses	**06**
	Common compulsory courses	**05**
FSC 591	Seminar	0+1
FSC 599	Research	0+30
	Total Credits	**70**

*Compulsory among major courses

Course Contents
M.Sc. (Hort.) in Fruit Science

I. Course Title : Tropical Fruit Production
II. Course Code : FSC 501
III. Credit Hours : (2+1)

IV. Why this course ?

Tropical fruits occupy a distinct place in global fruit production. Apart from ecological specificities, tropical fruits enjoy favour among masses being delicious and nutritious. As such, the course has been designed to provide update knowledge on various production technologies of tropical fruits on sustainable basis.

V. Aim of the course

To impart comprehensive knowledge to the students on cultural and management practices for growing tropical fruits.

The course is organised as follows:

No.	Blocks	Units	
1	Introduction	I	Importance and Background
2	Agro-Techniques	I	Propagation, Planting and Orchard Floor Management
3	Crop Management	I	Flowering, Fruit-Set and Harvesting

VI. Theory

Block 1: Introduction

Unit I: Importance and Background: Importance, origin and distribution, major species, rootstocks and commercial varieties of regional, national and international importance, eco-physiological requirements.

Block 2: Agro-techniques

Unit I: Propagation, Planting and Orchard Floor Management: Asexual and sexual methods of propagation, planting systems and planting densities, training and pruning methods, rejuvenation, intercropping, nutrient management, water management, fertigation, use of bio-fertilizers, role of bio-regulators, abiotic factors limiting fruit production.

Block 3: Crop Management

Unit I: Flowering, Fruit-Set and Harvesting: Physiology of flowering, pollination management, fruit set and development, physiological disorders – causes and remedies, crop regulation, quality improvement by management practices; maturity indices, harvesting, grading, packing, storage and ripening techniques; insect and disease management.

Crops

Mango, Banana, Guava, Pineapple, Papaya, Avocado, Jackfruit, Annonas, Aonla, Ber, etc.

VII. Practicals

- Distinguished features of tropical fruit species, cultivars and rootstocks (2);
- Demonstration of planting systems, training and pruning (3);
- Hands on practices on pollination and crop regulation (2);
- Leaf sampling and nutrient analysis (3);
- Physiological disorders-malady diagnosis (1);
- Physico-chemical analysis of fruit quality attributes (3);
- Field/ Exposure visits to tropical orchards (1);
- Project preparation for establishing commercial orchards (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The students are expected to equip themselves with know-how on agro-techniques for establishment and management of an orchard leading to optimum and quality fruit production of tropical fruits.

X. Suggested Reading

Bartholomew DP, Paull RE and Rohrbach KG. 2002. *The Pineapple: Botany, Production, and Uses*. CAB International.

Bose TK, Mitra SK and Sanyal D. 2002. *Fruits of India – Tropical and Sub-Tropical*.3rd Edn. Naya Udyog, Kolkata.

Dhillon WS. 2013. *Fruit Production in India*. Narendra Publ. House, New Delhi.

Iyer CPA and Kurian RM. 2006. *High Density Planting in Tropical Fruits: Principlesand Practices*. IBDC Publishers, New Delhi.

Litz RE. 2009. *The Mango: Botany, Production and Uses*. CAB International.

Madhawa Rao VN. 2013. *Banana*. ICAR, New Delhi.

Midmore D. 2015. *Principles of Tropical Horticulture*. CAB International.

Mitra SK and Sanyal D. 2013. *Guava,* ICAR, New Delhi.

Morton JF. 2013. *Fruits of Warm Climates*. Echo Point Book Media, USA.

Nakasome HY and Paull RE. 1998. *Tropical Fruits*. CAB International.

Paull RE and Duarte O. 2011. *Tropical Fruits* (Vol. 1). CAB International.

Rani S, Sharma A and Wali VK. 2018. *Guava* (*Psidium guajava* L.). Astral, New Delhi.

Robinson JC and Saúco VG. 2010. *Bananas and Plantains*. CAB International.

Sandhu S and Gill BS. 2013. *Physiological Disorders of Fruit Crops*. NIPA, New Delhi.

Schaffer B, Wolstenholme BN and Whiley AW. 2013. *The Avocado: Botany, Production and Uses*. CAB International.

Sharma KK and Singh NP. 2011. *Soil and Orchard Management*. Daya Publishing House, New Delhi.

Valavi SG, Peter KV and Thottappilly G. 2011. *The Jackfruit*. Stadium Press, USA.

I. **Course Title** : **Subtropical and Temperate Fruit Production**
II. **Course Code** : **FSC 502**
III. **Credit Hours** : **(2+1)**

IV. Why this course ?

Agro-climatic diversity in India facilitates growing a wide range of fruits extending from tropical to subtropical to temperate fruits and nuts. To highlight their ecological specificities, seasonal variations and pertinent cultural practices, a course is designed exclusively for subtropical and temperate fruits.

V. Aim of the course

To impart comprehensive knowledge to the students on cultural and management practices for growing subtropical and temperate fruits.

The course is organised as follows:

No.	Blocks	Units
1	Introduction	Importance and Background
2	Agro-Techniques	Propagation, Planting and Orchard Floor Management
3	Crop Management	Flowering, Fruit-Set and Harvesting

VI. Theory

Block 1: Introduction

Unit I: Importance and Background: Origin, distribution and importance, major species, rootstocks and commercial varieties of regional, national and international importance, eco-physiological requirements.

Block 2: Agro-Techniques

Unit I: Propagation, Planting and Orchard Floor Management: Propagation, planting systems and densities, training and pruning, rejuvenation and replanting, intercropping, nutrient management, water management, fertigation, use of bio-fertilizers, role of bio-regulators, abiotic factors limiting fruit production.

Block 3: Crop Management

Unit I: Flowering, Fruit-Set and Harvesting: Physiology of flowering, pollination management, fruit set and development, physiological disorders- causes and remedies, crop regulation, quality improvement by management practices; maturity indices, harvesting, grading, packing, storage and ripening techniques; insect and disease management.

Crops

Citrus, Grapes, Litchi, Pomegranate, Apple, Pear, Peach, Plum, Apricot, Cherries, Berries, Persimmon, Kiwifruit, Nuts- Walnut, Almond, Pecan, etc.

VII. Practicals

- Distinguished features of fruit species, cultivars and rootstocks (2);
- Demonstration of planting systems, training and pruning (3);
- Hands on practices on pollination and crop regulation (2);
- Leaf sampling and nutrient analysis (3);

- Physiological disorders-malady diagnosis (1);
- Physico-chemical analysis of fruit quality attributes (3);
- Field/ Exposure visits to subtropical and temperate orchards (1);
- Project preparation for establishing commercial orchards (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the student are expected to equip themselves with principles and practices of producing subtropical (citrus, grapes, litchi, pomegranate, etc.) and temperate fruits (apple, pear, peach, plum, apricot, cherries, berries, kiwifruit, etc.) and nuts (almond, walnut, pecan, etc.)

X. Suggested Reading

Chadha KL and Awasthi RP. 2005. *The Apple*. Malhotra Publishing House, New Delhi.
Chadha TR. 2011. *A Text Book of Temperate Fruits*. ICAR, New Delhi
Childers NF, Morris JR and Sibbett GS. 1995. *Modern Fruit Science: Orchard and Small Fruit Culture*. Horticultural Publications, USA.
Creasy G and Creasy L. 2018. *Grapes*. CAB International.
Davies FS and Albrigo LG. 1994. *Citrus.* CAB International.
Dhillon WS. 2013. *Fruit Production in India.* Narendra Publishing House, New Delhi.
Jackson D, Thiele G, Looney NE and Morley-Bunker M. 2011. *Temperate and Subtropical Fruit Production.* CAB International.
Ladanyia M. 2010. *Citrus Fruit: Biology, Technology and Evaluation*. Academic Press.
Layne DR and Bassi D. 2008. *The Peach: Botany, Production and Uses*. CABI.
Menzel CM and Waite GK. 2005. *Litchi and Longan: Botany, Production and Uses*. CAB International.
Pandey RM and Randey SN. 1996. *The Grape in India*. ICAR, New Delhi.
Rajput CBS, and Haribabu RS. 2006. *Citriculture,* Kalyani Publishers, New Delhi.
Sandhu S and Gill BS. 2013. *Physiological Disorders of Fruit Crops*. NIPA, New Delhi.
Sharma RM, Pandey SN and Pandey V. 2015. *The Pear – Production, Post-harvest Management and Protection*. IBDC Publisher, New Delhi.
Sharma RR and Krishna H. 2018. *Textbook of Temperate Fruits.* CBS Publishers and Distributors Pvt. Ltd., New Delhi.
Singh S, Shivshankar VJ, Srivastava AK and Singh IP. 2004. *Advances in Citriculture.* NIPA, New Delhi.
Tromp J, Webster AS and Wertheim SJ. 2005. *Fundamentals of Temperate Zone Tree Fruit Production.*Backhuys Publishers, Lieden, The Netherlands.
Webster A and Looney N. *Cherries: Crop Physiology, Production and Uses.* CABI.
Westwood MN. 2009. *Temperate Zone Pomology:Physiology and Culture.* Timber Press, USA.

I. Course Title : Propagation and Nursery Management in Fruit Crops
II. Course Code : FSC 503
III. Credit Hours : (2+1)

IV. Why this course ?

Availability of sufficient and healthy planting material is pivotal for expanding fruit culture. This necessitates requisite skill and efficient multiplication protocols for raising plants and their in house management prior to distribution or field transfer, hence the course is developed.

V. Aim of the course

To understand the principles and methods of propagation and nursery management in fruit crops.

The course is organised as follows:

No.	Blocks	Units
1	Introduction	I General Concepts and Phenomena
2	Propagation	I Conventional Asexual Propagation
		II Micropropagation
3	Nursery	I Management Practices and Regulation

VI. Theory

Block 1: Introduction

Unit 1: General Concepts and Phenomena: Introduction, understanding cellular basis for propagation, sexual and asexual propagation, apomixis, polyembryony, chimeras. Factors influencing seed germination of fruit crops, dormancy, hormonal regulation of seed germination and seedling growth. Seed quality, treatment, packing, storage, certification and testing.

Block 2: Propagation

Unit I: Conventional Asexual Propagation: Cutting– methods, rooting of soft and hardwood cuttings under mist and hotbeds. Use of PGR in propagation, Physiological, anatomical and biochemical aspects of root induction in cuttings. Layering – principle and methods.

Budding and grafting – principles and methods, establishment and management of bud wood bank. Stock, scion and inter stock relationship – graft incompatibility, physiology of rootstock and top working.

Unit II: Micropropagation: Micro-propagation – principles and concepts, commercial exploitation in horticultural crops. Techniques – *in-vitro* clonal propagation, direct organogenesis, embryogenesis, micrografting, meristem culture, genetic fidelity testing. Hardening, packaging and transport of micro-propagules.

Block 3: Nursery

Unit I: Management Practices and Regulation: Nursery – types, structures, components, planning and layout. Nursery management practices for healthy propagule production. Nursery Act, nursery accreditation, import and export of seeds and planting material and quarantine.

VII. Practical

- Hands on practices on rooting of dormant and summer cuttings (3);
- Anatomical studies in rooting of cutting and graft union(1);
- Hands on practices on various methods of budding and grafting (4);
- Propagation by layering and stooling (2);

- Micropropagation- explant preparation, media preparation, culturing – meristem tip culture, axillary bud culture, micro-grafting, hardening (4);
- Visit to commercial tissue culture laboratories and accredited nurseries (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The student would be expected to equip to acquire skills and knowledge on principles and practices of macro and micropropagation and the handling of propagated material in nursery.

X. Suggested Reading

Bose TK, Mitra SK and Sadhu MK. 1991. *Propagation of Tropical and Subtropical Horticultural Crops*. Naya Prokash, Kolkatta.

Davies FT, Geneve RL and Wilson SB. 2018. *Hartmann and Kester's Plant Propagation-Principles and Practices*. Pearson, USA/ PrenticeHall of India. New Delhi.

Gill SS, Bal JS and Sandhu AS. 2016. *Raising Fruit Nursery*. Kalyani Publishers,New Delhi.

Jain S and Ishil K. 2003. *Micropropagation of Woody Trees and Fruits*. Springer.

Jain S and Hoggmann H. 2007. *Protocols for Micropropagation of Woody Trees and Fruits*. Springer.

Joshi P. 2015. *Nursery Management of Fruit Crops in India*. NIPA, New Delhi.

Love *et al*. 2017. *Tropical Fruit Tree Propagation Guide*. UH-CTAHR F_N_49. College of Tropical Agriculture and Human Resources University of Hawaii at Manwa, USA.

Peter KV, eds. 2008. *Basics of Horticulture*. New India Publishing Agency, New Delhi.

Rajan S and Baby LM. 2007. *Propagation of Horticultural Crops*. NIPA, New Delhi.

Sharma RR. 2014. *Propagation of Horticultural Crops*. Kalyani Publishers, New Delhi.

Sharma RR and Srivastav M. 2004. *Propagation and Nursery Management*. Intl. Book Publishing Co., Lucknow.

Singh SP. 1989. *Mist Propagation*. Metropolitan Book Co.

Singh RS. 2014. *Propagation of Horticultural Plants: Arid and Semi-Arid Regions*. NIPA, New Delhi.

Tyagi S. 2019. *Hi-Tech Horticulture*. Vol I: *Crop Improvement, Nursery and Rootstock Management*. NIPA, New Delhi.

I. Course Title : Breeding of Fruit Crops

II. Course Code : FSC 504

III. Credit Hours : (2+1)

IV. Why this course ?

Development of genetically improved varieties and rootstock is a continuous process which is realized through selection and breeding approaches. This is necessary to enhance the productivity and meet ever-changing climatic conditions and market/ consumer preferences. As such, a course is formulated to generate know-how on genetic and breeding aspects of fruit crops.

V. Aim of the course

To impart comprehensive knowledge on principles and practices of fruit breeding.

The course organisation is as under:

No.	Blocks	Units
1	Introduction	Importance, Taxonomy and Genetic Resources
2	Reproductive Biology	Blossom Biology and Breeding Systems
3	Breeding approaches	Conventional and Non-Conventional Breeding

VI. Theory

Block 1: Introduction

Unit I: Importance, Taxonomy and Genetic Resources: Introduction and importance, origin and distribution, taxonomical status – species and cultivars, cytogenetics, genetic resources.

Block 2: Reproductive Biology

Unit I: Blossom Biology and Breeding Systems: Blossom biology, breeding systems – spontaneous mutations, polyploidy, incompatibility, sterility, parthenocarpy, apomixis, breeding objectives, ideotypes.

Block 3: Breeding Approaches

Unit I: Conventional and Non-Conventional Breeding: Approaches for crop improvement – direct introduction, selection, hybridization, mutation breeding, polyploid breeding, rootstock breeding, improvement of quality traits, resistance breeding for biotic and abiotic stresses, biotechnological interventions, achievements and future thrusts.

Crops

Mango, Banana, Pineapple, Citrus, Grapes, Litchi, Guava, Pomegranate, Papaya, Apple, Pear, Plum, Peach, Apricot, Cherries, Strawberry, Kiwifruit, Nuts

VII. Practicals

- Exercises on bearing habit, floral biology (2);
- Pollen viability and fertility studies (1);
- Hands on practices in hybridization (3);
- Raising and handling of hybrid progenies (2);
- Induction of mutations and polyploidy (2);
- Evaluation of biometrical traits and quality traits (2);
- Screening for resistance against abiotic stresses (2);
- Developing breeding programme for specific traits (2);
- Visit to research stations working on fruit breeding (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the students are expected to

- Have an understanding on importance and peculiarities of fruit breeding

- Have an updated knowledge on reproductive biology, genetics and inherent breeding systems.
- Have detailed knowledge of various methods/ approaches of breeding fruit crops

X. Suggested Reading

Abraham Z. 2017. *Fruit Breeding*. Agri-Horti Press, New Delhi.

Badenes ML and Byrne DH. 2012. *Fruit Breeding*. Springer Science, New York.

Dinesh MR. 2015. *Fruit Breeding*, New India Publishing Agency, New Delhi.

Ghosh SN, Verma MK and Thakur A. 2018. *Temperate Fruit Crop Breeding- Domestication to Cultivar Development*. NIPA, New Delhi.

Hancock JF. 2008. *Temperate Fruit Crop Breeding: Germplasm to Genomics*. Springer Science, New York.

Jain SN and Priyadarshan PM. 2009. *Breeding Plantation and Tree Crops: Tropical Species*. Springer Science, New York.

Jain S and Priyadarshan PM. 2009. *Breeding Plantation and Tree Crops: Temperate Species*. Springer Science, New York.

Janick J and Moore JN. 1996. *Fruit Breeding*. Vols. I–III. John Wiley & Sons, USA.

Kumar N. 2014. *Breeding of Horticultural Crops:Principles and Practices*. NIPA, N. Delhi.

Moore JN and Janick J. 1983. *Methods in Fruit Breeding*. Purdue University Press, USA.

Ray PK. 2002. *Breeding Tropical and Subtropical Fruits*. Narosa Publ. House, New Delhi.

I. Course Title : Systematics of Fruit Crops

II. Course Code : FSC 505

III. Credit Hours : (2+1)

IV. Why this course ?

Life forms and their behaviour are best understood if properly described to the stake holders. Therefore, identification and characterization are pre-requisites to distinctly describe the plant species. The fruit crop species are no exception, and thus an exclusive course on their categorisation and description exhibiting a great deal of variation.

V. Aim of the course

To acquaint with the classification, nomenclature and description of various fruit crops.

The course is organised as under:

No.	Blocks	Units
1	Biosystematics	Nomenclature and Classification
2	Botanical Keys and Descriptors	Identification and Description
3	Special Topics	Registration and Modern Systematics

VI. Theory

Block 1: Biosystematics

Unit I: Nomenclature and Classification: Biosystematics – introduction and significance; history of nomenclature of cultivated plants, classification and nomenclature systems; International code of nomenclature for cultivated plants

Block 2: Botanical Keys and Descriptors

Unit I: Identification and Description: Methods of identification and description of cultivated fruit and nut species and their wild relatives features; development of plant keys for systematic identification and classification.

Development of fruit crop descriptors- based upon Bioversity International Descriptors and UPOV/ DUS test guidelines, botanical and pomological description of major cultivars and rootstocks of tropical, subtropical and temperate fruits and nut crops

Block 3: Special Topics

Unit I: Registration and Modern Systematics: Registration, Use of chemotaxonomy, biochemical and molecular markers in modern systematics

VII. Practicals

- Exercises on identification and pomological description of various fruit species and cultivars (6);
- Development of descriptive blanks *vis-a-vis* UPOV/ DUS test guidelines and Bioversity International (4);
- Descriptors for developing fruit species and cultivar descriptive databases (4);
- Visits to major germplasm centres and field genebanks (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the students would be able to—

- Categorise different fruit species into broad groups.
- Identify various fruit cultivars on basis of distinguishing features
- Characterize fruit cultivars for description, registration and protection

X. Suggested Reading

ASHS. 1997. *The Brooks and Olmo Register of Fruit and NutVarieties*. 3rd Ed. ASHS Press.

Bhattacharya B and Johri BM. 2004. *Flowering Plants: Taxonomy and Phylogeny*. Narosa Pub. House, New Delhi.

Pandey BP. 1999. *Taxonomy of Angiosperms*. S. Chand & Co. New Delhi.

Pareek OP and Sharma S. 2017. *Systematic Pomology*. Scientific Publishers, Jodhpur.

Sharma G, Sharma OC and Thakur BS. 2009. *Systematics of Fruit Crops*. NIPA, New Delhi.

Simpson M. 2010. *Plant Systematics*. 2ndEdn. Elsevier.

Spencer RR, Cross R and Lumley P. 2003. *Plant Names*. 3rd Ed. *A Guide to Botanical Nomenclature,* CISRO, Australia.

Srivastava U, Mahajan RK, Gangopadyay KK, Singh M and Dhillon BS. 2001. *Minimal Descriptors of Agri-Horticultural Crops. I: Fruits*. NBPGR, New Delhi.

Zielinski QB. 1955. *Modern Systematic Pomology*. Wm. C. Brown Co., Iowa, USA.

I. Course Title : Canopy Management of Fruit Crops

II. Course Code : FSC 506

III. Credit Hours : (1+1)

IV. Why this course ?

Plant architecture plays an important role in enhancing photosynthetic efficiency and resultant quantity and quality of the fruit produce. Manipulation of plant growth and development can be done by employing different training and pruning procedures besides through the use of growth regulators, specific rootstocks, etc. Hence this course is developed to address the aforesaid issues.

V. Aim of the course

To impart knowledge on principles and practices in management of canopy architecture for quality fruit production.

The course organisation is as follows:

No.	Blocks	Units
1	Canopy Architecture	Introduction, types and Classification
2	Canopy Management	Physical Manipulation and Growth regulation

VI. Theory

Block 1: Canopy Architecture

Unit I: Introduction, Types and Classification: Canopy management – importance and factors affecting canopy development. Canopy types and structures, canopy manipulation for optimum utilization of light and its interception. Spacing and utilization of land area – Canopy classification.

Block 2: Canopy Management

Unit I: Physical Manipulation and Growth Regulation: Canopy management through rootstock and scion. Canopy management through plant growth regulators, training and pruning and management practices. Canopy development and management in relation to growth, flowering, fruiting and fruit quality.

VII. Practicals

- Study of different types of canopies (2);
- Training of plants for different canopy types (2);
- Canopy development through pruning (2);
- Understanding bearing behaviour and canopy management in different fruits (2);
- Use of plant growth regulators (2);
- Geometry of planting (1);
- Development of effective canopy with support system (2);
- Study on effect of different canopy types on production and quality of fruits (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations

- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the students are expected to learn

- The basic principles of canopy management to modify plant architecture
- The skills on training and pruning of fruit crops, and growth regulation

X. Suggested Reading

Bakshi JC, Uppal DK and Khajuria HN. 1988. *The Pruning of Fruit Trees and Vines*. Kalyani Publishers, New Delhi.

Chadha KL and Shikhamany SD. 1999. *The Grape, Improvement, Production and Post Harvest Management*. Malhotra Publishing House, Delhi.

Iyer CPA and Kurian RM. 2006. *High Density Planting in Tropical Fruits: Principles and Practices*. IBDC Publishers, New Delhi.

Pradeepkumar T. 2008. *Management of Horticultural Crops*. NIPA, New Delhi.

Singh G. 2010. *Practical Manual on Canopy Management in Fruit Crops*. Dept. of Agriculture and Co-operation, Ministry of Agriculture (GoI), New Delhi.

Srivastava KK. 2012. *Canopy Management in Fruits*. ICAR, New Delhi

I. Course Title : Growth and Development of Fruit Crops

II. Course Code : FSC 507

III. Credit Hours : (2+1)

IV. Why this course ?

The underlying principles and parameters of growth and development needs to be understood for harnessing maximum benefits in term of yield and quality. External environment and inherent hormonal and metabolic pathways considerably determine growth dynamics. Thus, a course is formulated to develop know-how on physiological and physical aspects of growth and development processes.

V. Aim of the course

To develop comprehensive understanding on growth and development of fruit crops.

The course is structured as under:-

No.	Blocks	Units
1	Introduction	General Concepts and Principles
2	Environment and Development	Climatic Factors, Hormones and Developmental Physiology
3	Stress Management	Strategies for Overcoming Stress

VI. Theory

Block 1: Introduction

Unit I: General Concepts and Principles: Growth and development- definition, parameters of growth and development, growth dynamics and morphogenesis.

Block 2: Environment and Development

Unit I: Climatic Factors, Hormones and Developmental Physiology: Environmental impact on growth and development- effect of light, temperature, photosynthesis and photoperiodism, vernalisation, heat units and thermoperiodism. Assimilate partitioning, influence of water and mineral nutrition in growth and development; concepts of plant hormone and bioregulators, history, biosynthesis and physiological role of auxins, gibberellins, cytokinins, abscissic acid, ethylene, growth inhibitors and retardant, brasssinosteroids, other New PGRs. Developmental physiology and biochemistry during dormancy, bud break, juvenility, vegetative to reproductive interphase, flowering, pollination, fertilization and fruit set, fruit drop, fruit growth, ripening and seed development.

Block 3: Stress Management

Unit I: Strategies for Overcoming Stress: Growth and developmental process during stress – manipulation of growth and development, impact of pruning and training, chemical manipulations and Commercial application of PGRs in fruit crops, molecular and genetic approaches in plant growth and development.

VII. Practicals

- Understanding dormancy mechanisms in fruit crops and seed stratification (2);
- Techniques of growth analysis (2);
- Evaluation of photosynthetic efficiency under different environments (2);
- Exercises on hormone assays (2);
- Practicals on use of growth regulators (2);
- Understanding ripening phenomenon in fruits (2);
- Study on impact of physical manipulations on growth and development (1);
- Study on chemical manipulations on growth and development (1);
- Understanding stress impact on growth and development (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

Consequent upon successful completion of the course, the students are expected to have

- Equipped with understanding of various growth and development processes
- Learned about the role of environment and growth substances
- Acquired the skills to realise optimum growth and development under stress conditions

X. Suggested Reading

Bhatnagar P. 2017. *Physiology of Growth and Development of Horticultural Crops*. Agrobios (India).

Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. John Wiley & Sons, NY, USA.

Dhillon WS and Bhatt ZA. 2011. *Fruit Tree Physiology*. Narendra Publishing House, New Delhi.

Durner E. 2013. *Principles of Horticultural Physiology*. CAB International.

Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*. John Wiley & Sons, NY, USA.
Faust M. 1989. *Physiology of Temperate Zone Fruit Trees*. John Willey & Sons, NY, USA.
Fosket DE. 1994. *Plant Growth and Development: a Molecular Approach*. Academic Press, USA.
Leopold AC and Kriedermann PE. 1985. *Plant Growth and Development*. 3rd Ed. McGraw-Hill, New Delhi.
Roberts J, Downs S and Parker P. 2002. Plant Growth Development. In: Salisbury FB and Ross CW. (Eds.) *Plant Physiology*. 4th Ed.Wadsworth Publications, USA.
Schafeer, B. and Anderson, P. 1994. *Handbook of Environmental Physiology of Fruit Crops*. Vol. 1 & 2. CRC Press. USA.
Seymour GB, Taylor JE and Tucker GA. 1993. *Biochemistry of Fruit Ripening*. Chapman & Hall, London.

I. Course Title : Nutrition of Fruit Crops

II. Course Code : FSC 508

III. Credit Hours : (2+1)

IV. Why this course ?

Nutrients play a significant role in almost every growth and development process determining vigour, yield and quality of fruits. Henceforth, a course is designed to have an in depth study of various nutrients, their uptake and use efficiency in realizing sustainable fruit production

V. Aim of the course

To acquaint with principles and practices involved in nutrition of fruit crops
The course is organised as under:-

No.	Blocks	Units
1	Introduction	General Concepts and Principles
2	Requirements and Applications	Diagnostics, Estimation and Application
3	Newer Approaches	Integrated Nutrient Management (INM)

VI. Theory

Block 1: Introduction

Unit I: General Concepts and Principles: Importance and history of nutrition in fruit crops, essential plant nutrients, factors affecting plant nutrition; nutrient uptake and their removal from soil.

Block 2: Requirements and Applications

Unit I: Diagnostics, Estimation and Application: Nutrient requirements, root distribution in fruit crops, soil and foliar application of nutrients in major fruit crops, fertilizer use efficiency. Methods and techniques for evaluating the requirement of macro- and micro-elements, Diagnostic and interpretation techniques including DRIS. Role of different macro- and micro-nutrients, their deficiency and toxicity disorders, corrective measures to overcome deficiency and toxicity disorders.

Block 3: Newer Approaches

Unit I: Integrated Nutrient Management (INM): Fertigation in fruit crops, bio-fertilizers and their use in INM systems.

VII. Practicals

- Visual identification of nutrient deficiency symptoms in fruit crops (2);
- Identification and application of organic, inorganic and bio-fertilizers (1);
- Soil/ tissue collection and preparation for macro- and micro-nutrient analysis (1);
- Analysis of soil physical and chemical properties- pH, EC, Organic carbon (1);
- Determination of N,P,K and other macro- and micronutrients (6);
- Fertigation in glasshouse and field grown horticultural crops (2);
- Preparation of micro-nutrient solutions, their spray and soil applications (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the students would be expected to

- Know the importance and various types of nutrients and their uptake mechanisms
- Analyse soil and plant status with respect to various nutrients
- Make use of corrective measures to overcome deficiency or toxicity

X. Suggested Reading

Atkinson D, Jackson JE and Sharples RO. 1980. *Mineral Nutrition of Fruit Trees*. Butterworth – Heinemann.

Bould C, Hewitt EJ and Needham P. 1983. *Diagnosis of Mineral Disorders in Plants Vol.1 Principles.* Her Majesty's Stationery Office, London.

Cooke GW. 1972. *Fertilizers for maximizing yield*. Grenada Publishing Ltd, London.

Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*. Wiley Eastern Ltd.

Kanwar JS. 1976. *Soil Fertility-Theory and Practice*. ICAR, New Delhi.

Marchner Horst. 1995. *Mineral Nutrition of Higher Plants*, 2nd Ed. Marschner, Academic Press Inc. San Diego, CA.

Mengel K and Kirkby EA. 1987. *Principles of Plant Nutrition*. 4th Ed. International Potash Institute, Worblaufen-Bern, Switzerland.

Prakash M. 2013. *Nutritional Disorders in Fruit Crops: Diagnosis and Management*. NIPA, New Delhi.

Tandon HLS. 1992. *Management of Nutrient Interactions in Agriculture*. Fertilizer Development and Consultation Organization, New Delhi.

Westerman RL. 1990. *Soil Testing and Plant Analysis*, 3rd Ed. Soil Science Society of America, Inc., Madison, WI.

Yawalkar KS, Agarwal JP and Bokde S. 1972. *Manures and Fertilizers*. 3rd Ed. Agri Horticultural Publishing House, Nagpur.

I. Course Title : Biotechnology of Fruit Crops

II. Course Code : FSC 509

III. Credit Hours : (2+1)

IV. Why this course ?

In the recent times, biotechnological interventions in fruit crops have contributed in enhanced yield, biotic and abiotic stress management and improved quality traits to a considerable extent. Hence, a course is designed to educate on the possibilities and progress made through biotechnology for improved fruit production.

V. Aim of the course

To impart knowledge on the principles and tools of biotechnology.

Structure of the course is as under:

No.	Blocks	Units
1	General Background	Introduction, History and Basic Principles
2	Tissue Culture	*In-vitro* Culture and Hardening
3	Genetic Manipulation	*In-vitro* Breeding, Transgenics and Gene Technologies

VI. Theory

Block 1: General Background

Unit I: Introduction, History and Basic Principles: Introduction and significance, history and basic principles, influence of explant material, physical, chemical factors and growth regulators on growth and development of plant cell, tissue and organ culture.

Block 2: Tissue Culture

Unit I: *In-vitro* Culture and Hardening: Callus culture – types, cell division, differentiation, morphogenesis, organogenesis, embryogenesis; Organ culture – meristem, embryo, anther, ovule culture, embryo rescue, somaclonal variation, protoplast culture. Use of bioreactors and *in-vitro* methods for production of secondary metabolites, suspension culture, nutrition of tissues and cells, regeneration of tissues. Hardening and *ex vitro* establishment of tissue cultured plants.

Block 3: Genetic Manipulation

Unit I: *In-vitro* Breeding, Transgenics and Gene Technologies: Somatic cell hybridisation, construction and identification of somatic hybrids and cybrids, wide hybridization, *in-vitro* pollination and fertilization, haploids, *in-vitro* mutation, artificial seeds, cryopreservation, *In-vitro* selection for biotic and abiotic stress. Genetic engineering- principles and methods, transgenics in fruit crops, use of molecular markers and genomics. Gene silencing, gene tagging, gene editing, achievements of biotechnology in fruit crops.

VII. Practicals

- An exposure to low cost, commercial and homestead tissue culture laboratories (2);
- Media preparation, Inoculation of explants for clonal propagation, callus induction and culture, regeneration of plantlets from callus (3);
- Sub-culturing techniques on anther, ovule, embryo culture, somaclonal variation (4);
- *In-vitro* mutant selection against abiotic stress (2);
- Protoplast culture and fusion technique (2);
- Development of protocols for mass multiplication (2);
- Project development for establishment of commercial tissue culture laboratory (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals

- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After the successful completion of the course, the students are expected to know

- Basic principles and methods of plant tissue culture and other biotechnological tools.
- The use and progress of biotechnology in fruit crops.

X. Suggested Reading

Bajaj YPS. Eds., 1989. *Biotechnology in Agriculture and Forestry*. Vol. V, *Fruits*. Springer, USA.

Brown TA. 2001. *Gene Cloning and DNA Analysis and Introduction.* Blackwell Publishing, USA.

Chahal GS and Gosal SS. 2010. *Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches*. Narosa, New Delhi.

Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology – Concepts, Methods and Applications.* Oxford & IBH, New Delhi.

Kale C. 2013. Genome Mapping and Molecular Breeding in Plant, Vol 4. *Fruit and Nuts.* Springers.

Keshavachandran R and Peter KV. 2008. *Plant Biotechnology: Tissue Culture and Gene Transfer*. Orient & Longman, Universal Press, US.

Keshavachandran R, Nazeem PA, Girija D, John PS and Peter KV. 2007. *Recent Trends in Biotechnology of Horticultural Crops*. Vols. I, II. NIPA, New Delhi.

Litz RE. 2005. *Biotechnology of Fruit and Nut Crops.* CABI, UK.

Miglani GS. 2016. *Genetic Engineering – Principles, Procedures and Consequences*. Narosa Publishing House, New Delhi.

Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK and Mohanadas S. 2001. *Biotechnology of Horticultural Crops*. Vols. I–III. Naya Prokash, Kolkata.

Peter KV. 2013. *Biotechnology in Horticulture: Methods and Applications*. NIPA, New Delhi.

Vasil TK, Vasi M, While DNR and Bery HR. 1979. *Somatic Hybridization and Genetic Manipulation in Plants. Plant Regulation and World Agriculture*. Platinum Press, UK.

I. Course Title : Organic Fruit Culture

II. Course Code : FSC 510

III. Credit Hours : (2+1)

IV. Why this course ?

Considering threats to environment and human health on account of excessive use of chemicals and synthetic fertilizers, organic farming is looked upon as an alternative. Though the organic and other natural farming practices are in evolving phase and are yet to be time scale tested, there is a general perception that these would hold good. As such a course is customised to educate the Graduates on various issues related to organic farming.

V. Aim of the course

To develop understanding on organic production of fruit crops.

The course is structured as under:-

No.	Blocks	Units
1	General Aspects	Principles and Current Scenario
2	Organic Culture	Farming System and Practices
3	Certification	Inspection, Control Measures and Certification

VI. Theory

Block 1: General Aspects

Unit I: Principles and Current Scenario: Organic horticulture, scope, area, production and world trade, definition, principles, methods and SWOT analysis.

Block 2: Organic Culture

Unit I: Farming System and Practices: Organic farming systems including biodynamic farming, natural farming, homa organic farming, rishi krishi, EM technology, cosmic farming; on-farm and off-farm production of organic inputs, role of bio-fertilizers, bio enhancers, legumes, inter cropping, cover crops, green manuring, zero tillage, mulching and their role in organic nutrition management. Organic seeds and planting materials, soil health management in organic production, weed management practices in organic farming, biological management of pests and diseases, trap crops, quality improvement in organic production of fruit crops.

Block 3: Certification

Unit I: Inspection, Control Measures and Certification: Inspection and certification of organic produce, participatory guarantee system (PGS), NPOP, documentation and control, development of internal control system (ICS), Concept of group certification, constitution of grower group as per NPOP, preparation of ICS manual, internal and external inspection, concept of third party verification, certification of small farmer groups (Group Certification), transaction certificate, group certificate, critical control points (CCP) and HACCP, IFOAM guidelines on certification scope and chain of custody, certification trademark – The Logo, accredited certification bodies under NPOP. Constraints in certification, IFOAM and global scenario of organic movement, postharvest management of organic produce. Economics of organic fruit production.

VII. Practicals

- Design of organic orchards/ farms management (1);
- Conversion plan (1);
- Nutrient management and microbial assessment of composts and bio-enhancers (2);
- Preparation and application of composts, bio-enhancers and bio-pesticides (2);
- Organic nursery raising (1);
- Application of composts, bio-enhancers, bio-fertilisers and bio-pesticides, green manure, cover, mulching (2);
- Preparation and use of neem based products (1);

- Biodynamic preparations and their role in organic agriculture, EM technology and products, biological/ natural management of pests and diseases (2);
- Soil solarisation (1);
- Frame work for GAP (1);
- Documentation for certification (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

On successful completion of the course, the students are expected to be able to

- Familiarize with the concepts and practices of organic and other natural farming systems
- Generate know-how on procedures, policies and regulation for inspection and certification of organic produce

X. Suggested Reading

Claude A. 2004. *The Organic Farming Sourcebook*. Other India Press, Mapusa, Goa, India.

Dabholkar SA. 2001. *Plenty for All*. Mehta Publishing House, Pune, Maharashtra.

Das HC and Yadav AK. 2018. *Advances in Organic Production of Fruit Crops*. Westville Publishing House, New Delhi.

Deshpande MS. 2003. *Organic Farming with respect to Cosmic Farming*. Mrs. Pushpa Mohan Deshpandey, Kolhapur, Maharashtra.

Deshpande WR. 2009. *Basics of Organic Farming*. All India Biodynamic and Organic Farming Association, Indore. MP.

Gaur AC, Neblakantan S and Dargan KS. 1984 *Organic Manures*. ICAR, New Delhi.

Lampkin, N. and Ipswich, S. 1990. *Organic Farming*. Farming Press. London, UK.

Lind K, Lafer G, Schloffer K, Innershofer G and Meister H. 2003. *Organic Fruit Growing*. CAB International.

Palaniappan SP and Annadurai K. 2008. *Organic Farming- Theory and Practice*. Scientific Publishers, Jodhpur, Rajasthan, India.

Palekar S. 2004. *The Technique of Spritual Farming*. Chandra Smaritee, Sai Nagar, Amrawati, Maharashtra.

Proctor P. 2008. Biodynamic Farming and Gardening. Other India Press, Mapusa, Goa.

Ram RA and Pathak RK. 2017. Bioenhancers. Lap Lambert Academic Publishing, AP.

I. Course Title : Export Oriented Fruit Production

II. Course Code : FSC 511

III. Credit Hours : (2+1)

IV. Why this course ?

India is a top ranking country in production of fruit crops especially with respect mangoes, bananas, and grapes. WTO regime opens new vistas for exploring export opportunities of different fruit commodities. Already, India export mangoes, litchi, grapes, walnuts, apples, etc. and there lies a huge potential in this sector. As such a course has been developed to highlights government policies, standards, infrastructural development and export potential vis-à-vis international scenario.

V. Aim of the course

To acquaints with the national and international standards and export potential of fruit crops

The course is organised as under:-

No.	Blocks	Units
1	Introduction	Statistics and World Trade
2	Regulations	Policies, Norms and Standards
3	Quality Assurance	Infrastructure and Plant Material

VI. Theory

Block 1: Introduction

Unit I: Statistics and World Trade: National and international fruit export and import scenario and trends; Statistics and India's position and potentiality in world trade; export promotion zones in India. Government Policies.

Block 2: Regulations

Unit I: Policies, Norms and Standards: Scope, produce specifications, quality and safety standards for export of fruits, viz., mango, banana, grape, litchi, pomegranate, walnut, apple and other important fruits. Processed and value-added products, post harvest management for export including packaging and cool chain; HACCP, Codex alimentarius, ISO certification; WTO and its implications, sanitary and phyto-sanitary measures.

Block 3: Quality Assurance

Unit I: Infrastructure and Plant Material: Quality fruit production under protected environment; different types of structures – Automated greenhouses, glasshouse, shade net, poly tunnels – Design and development of low cost greenhouse structures. Seed and planting material; meeting export standards, implications of plant variety protection – patent regimes.

VII. Practicals

- Export promotion zones and export scenario of fresh fruits and their products (1);
- Practical exercises on quality standards of fruits for export purpose (2);
- Quality standards of planting material and seeds (2);
- Hi-tech nursery in fruits (1);
- Practicals on ISO specifications and HACCP for export of fruits (3);
- Sanitary and phyto-sanitary measures during export of horticultural produce (2);
- Post harvest management chain of horticultural produce for exports (2);
- Visit to export oriented units/ agencies like APEDA, NHB, etc.

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

Consequent upon successful completion of the course, the students are expected to have learnt about

- National and international trade scenario of fruit crops
- Set norms and standards for export of fruit crops
- Requisite infrastructure and growing practices meeting export standards

X. Suggested Reading

Chadha KL. 1995. *Advances in Horticulture*. Vol. XII. Malhotra Publ. House, New Delhi.

Chetan GF. 2015. *Export Prospects of Fruits and Vegetables from India: A study of Export market in EU. A project report*. Anand Agricultural University, Anand, Gujarat.

Dattatreylul M. 1997. *Export potential of Fruits, Vegetables and Flowers from India*. NABARD, Mumbai.

Islam, C.N. 1990. *Horticultural Export of Developing Countries: Past Preferences, Future Prospects and Policies*. International Institute of Food Policy Research, USA.

e-Resources

http://apeda.gov.in
http://nhb.gov.in
http://indiastat.com

I. Course Title : Climate Change and Fruit Crops

II. Course Code : FSC 512

III. Credit Hours : (1+0)

IV. Why this course ?

In the changing climatic scenario, the fruit crops get affected adversely due to one or more unfavourable environmental factors. Shifting of temperate fruits to higher altitudes due to insufficient chilling, occurrence of drought and frost in warmer areas are notable examples. In order to educate on extent of damage and strategies to mitigate the effect of climate change, a course has been formulated.

V. Aim of the course

To understand the impact of climate change and its management in fruit production.

The course is structured as under:-

No.	Blocks	Units
1	General Aspects	Introduction, Global Warming and Climatic Variability
2	Climate Change and Management	Impact Assessment and Mitigation
3	Case Studies	Response to Climate Change

VI. Theory

Block 1: General Aspects

Unit I: Introduction, Global Warming and Climatic Variability: Introduction to climate change. Factors directly affecting climate change. Global warming, effect of climate change on spatio-temporal patterns of temperature and rainfall, concentrations of greenhouse gasses in atmosphere. pollution levels such as tropospheric ozone, change in climatic variability and extreme events.

Block 2: **Climate Change and Management**

Unit I: Impact Assessment and Mitigation: Sensors for recording climatic parameters, plants response to the climate changes, premature bloom, marginally overwintering or inadequate winter chilling hours, longer growing seasons and shifts in plant hardiness for fruit crops.

Climate mitigation measures through crop management- use of tolerant rootstocks and varieties, mulching – use of plastic- windbreak- spectral changes- protection from frost and heat waves. Climate management in greenhouse- heating – vents – CO_2 injection – screens – artificial light. Impact of climate changes on invasive insect, disease, weed, fruit yield, quality and sustainability. Climate management for control of pests, diseases, quality, elongation of growth and other plant processes- closed production systems.

Block 3: **Case Studies**

Unit I: Response to Climate Change: Case studies – responses of fruit trees to climatic variability *vis-a-vis* tolerance and adaptation; role of fruit tree in carbon sequestration.

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

After the successful completion of the course, the students are expected to have learnt

- Nature and extent of altered behaviour or damage due to climate change
- Methods to assess the adverse effects
- Approaches to mitigate the effect due to climatic variability

IX. Suggested Reading

Dhillon WS and Aulakh PS. 2011. *Impact of Climate Change in Fruit Production*. Narendra Publishing House, New Delhi.

Peter KV. 2008. *Basics in Horticulture*. New India Publishing Agency, New Delhi.

Ramirez F and Kallarackal J. 2015. *Responses of Fruit Trees to Global Climate Change*. Spinger-Verlag.

Rao GSLHV. 2008. *Agricultural Meteorology*. Prentice Hall, New Delhi.

Rao GSLHV, Rao GGSN, Rao VUM and Ramakrishnan YS. 2008. *Climate Change and Agriculture over India*. ICAR, New Delhi.

Schafeer B and Anderson P. 1994. *Handbook of Environmental Physiology of Fruit Crops*.Vol. 1 & 2. CRC Press. USA.

I. Course Title : Minor Fruit Production

II. Course Code : FSC 513

III. Credit Hours : (2+1)

IV. Why this course ?

Apart from commercially grown fruits, several other fruits inspite of being rich in nutrients and potential future crops, remains neglected/ underexploited. The hardy nature coupled with the possibility of diversification (newly domesticated crops) further adds to their importance. The course outlines the efforts made in standardizing agro-techniques for propagation and cultivation besides know-how on their nutraceutical value and other uses.

V. Aim of the course

To import basic knowledge underexploited minor fruit crops.

The course is structured as under:-

No.	Blocks	Units
1	Introduction	Occurrence, Adoption and General Account
2	Agro-Techniques	Propagation and Cultural Practices
3	Marketing and utilization	Post-Harvest Management

VI. Learning outcome

On successful completion of the course, the students are expected to know about

- Various minor fruits hitherto neglected and their commercial value
- Efforts made to domesticate minor fruits and standardization of agro-techniques.
- Their utilization in processing industry.

VII. Theory

Block 1: Introduction

Unit I: Occurrence, Adoption and General Account: Importance – occurrence and distribution, climate adaptation in fragile ecosystem and wastelands.

Block 2: Agro-Techniques

Unit I: Propagation and Cultural Practices: Traditional cultural practices and recent development in agro-techniques; propagation, botany-floral biology, growth patterns, mode of pollination, fruit set, ripening, fruit quality.

Block 3: Marketing and Utilization

Unit I: Post-Harvest Management: Post harvest management, marketing; minor fruit crops in terms of medicinal and antioxidant values; their uses for edible purpose and in processing industry

Crops

Bael, chironji, fig, passion fruit, jamun, phalsa, karonda, woodapple, cactus pear, khejri, kair, pilu, lasoda, loquat, tamarind, dragon fruit, monkey jack, mahua, khirni, amra, kokum, cape gooseberry, kaphal, persimmon, pistachio, seabuckthorn, hazel nut and other minor fruits of regional importance

VIII. Practicals

- Visits to institutes located in the hot and cold arid regions of the country (2);
- Identification of minor fruits plants/ cultivars (2);
- Collection of leaves and preparation of herbarium (1);
- Allelopathic studies (2);
- Generating know-how on reproductive biology of minor fruits (4);
- Fruit quality attributes and biochemical analysis (3);
- Project formulation for establishing commercial orchards in fragile ecosystems (1).

IX. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

X. Suggested Reading

Ghosh SN, Singh A and Thakur A. 2017. *Underutilized Fruit Crops: Importance and Cultivation*. Jaya Publication House, New Delhi.

Krishna H and Sharma RR, 2017. *Fruit Production: Minor Fruits*. Daya Publishing House, New Delhi.

Mazumdar BC. 2014. *Minor Fruit Crops of India: Tropical and Subtropical*. Daya Publication House, New Delhi.

Nath V, Kumar D, Pandey V and Pandey D. 2008. *Fruits for the Future*. Satish Serial Publishing House, New Delhi.

Pareek OP, Sharma S, and Arora RK. 2007. *Underutilised Edible Fruits and Nuts*, IPGRI, Rome.

Peter KV. 2010. *Underutilized and Underexploited Horticultural Crops*. NIPA, New Delhi.

Rana JC and Verma VD. 2011. *Genetic Resources of Temperate Minor Fruit* (*Indigenous and Exotic*). NBPGR, New Delhi.

Saroj PL and Awasthi OP. 2005. *Advances in Arid Horticulture*, Vol. II: *Production Technology of Arid and Semiarid Fruits*. IBDC, Lucknow.

Saroj PL, Dhandar DG and Vashishta BB. 2004. *Advances in Arid Horticulture*, Vol.-1 *Present Status*. IBDC, Lucknow.

Singh *et al*. 2011. *Jamun*. ICAR, New Delhi.

Course Title with Credit Load
Ph.D. (Hort.) in Fruit Science

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
FSC 601*	Innovative Approaches in Fruit Breeding	3+0
FSC 602*	Modern Trends in Fruit Production	3+0
FSC 603	Recent Developments in Growth Regulation	3+0
FSC 604	Advanced Laboratory Techniques	1+2
FSC 605	Arid and Dry Land Fruit Production	2+0
FSC 606	Abiotic Stress Management in Fruit Crops	2+1
FSC 607	Biodiversity and Conservation of Fruit Crops	2+1
FSC 608	Smart Fruit Production	2+0
	Minor courses	06
	Supporting courses	05
FSC 691	Seminar-I	0+1
FSC 692	Seminar-II	0+1
FSC 699	Research	0+75
	Total Credits	**100**

*Compulsory among major courses

Course Contents
Ph.D. (Hort.) in Fruit Science

I. Course Title : Innovative Approaches in Fruit Breeding

II. Course Code : FSC 601

III. Credit Hours : (3+0)

IV. Why this course ?

Modern day fruit culture witnesses rapid changes in production technologies and market trends. Ever changing environment and consumer preferences warrant constant development and adoption of genetically improved varieties.There is more thrust on novelty and distinctness in view of ever increasing competition with enhanced emphasis on tailor made and trait specific designer varieties and rootstocks. The course is thus designed to integrate updated information on inherent breeding systems and innovative gene manipulation technologies enhancing breeding efficiency.

V. Aim of the course

To update knowledge on current trends and innovative approaches in fruit breeding.

The structural organisation of the course is as under:-

No.	Blocks	Units
1	Introduction	Current Trends and Status
2	Genetic Mechanisms	Inheritance Patterns and Breeding Systems
3	Breeding for Specific Traits	Plant Architecture, Stress Tolerance and Fruit Quality
4	Fast-Track Breeding	Transgenics, Markers and Genomics

VI. Theory

Block 1: Introduction

Unit I: Current Trends and Status: Modern trends in fruit breeding –with major emphasis on precocity, low tree volume, suitability for mechanization, health benefits, etc.

Block 2: Genetic Mechanisms

Unit I: Inheritance Patterns and Breeding Systems: Genetics of important traits and their inheritance pattern, variations and natural selection, spontaneous mutations, incompatibility systems in fruits.

Block 3: Breeding for Specific Traits

Unit I: Plant Architecture, Stress Tolerance and Fruit Quality: Recent advances in crop improvement efforts- wider adaptation, plant architecture, amenability to mechanization, fruit quality attributes, stress tolerance, crop specific traits; use of apomixis, gene introgression and wide hybridization (alien genes).

Block 4: Fast-Track Breeding

Unit I: Transgenics, Markers and Genomics: Molecular and transgenic approaches in improvement of selected fruit crops; fast track breeding–marker assisted selection and breeding (MAS and MAB), use of genomics and gene editing tehnologies.

Crops

Mango, banana, guava, papaya, Citrus, grapes, pomegranate, litchi, apple, pear, strawberry, kiwifruit, plums, peaches, apricot, cherries, nectarines, nut crops

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

On successful completion of the course, the students are expected to

- Develop updated knowledge on current breeding objectives and trends
- Equip with information on innovative approaches enhancing breeding efficiency

IX. Suggested Reading

Al-Khayari J, Jain SN and Johnson DV. 2018. *Advances in Plant Breeding Strategies. Vol. 3: Fruits*. Springer.

Badenes S and Byrne DH. 2012. *Fruit Breeding*. Springer.

Hancock JF. 2008. *Temperate Fruit Crop Breeding: Germplasm to Genomics*. Springer.

Kole C and Abbott AG. 2012. *Genetics, Genomics and Breeding of Stone fruits*. CRC.

Kole, C. 2011. *Wild Crops Relatives: Genomics and Breeding Resources: Tropical and Subtropical Fruits*. Springer-Verlag.

Kole C. 2011. *Wild Crops Relatives: Genomics and Breeding Resource: Temperate Fruits*. Springer -Verlag.

Jain SN and Priyadarshan PM. 2009. *Breeding Plantation and Tree Crops: Tropical Species*; *Temperate Species*. Springer -Verlag.

Janick J and Moore JN, 1996. *Fruit Breeding*. Vols.I-III. John Wiley & Sons, USA.

Orton T. 2019. *Methods in Fruit Breeding*. Elsevier.

Singh SK, Patel VB, Goswami AK, Prakash J and Kumar C. 2019. *Breeding of Perennial Horticultural Crops*. Biotech Books. Delhi.

I. Course Title : Modern Trends in Fruit Production

II. Course Code : FSC 602

III. Credit Hours : (3+0)

IV. Why this course ?

Recent technological developments in propagation and cultural practices paves the way to grow fruit crops in an intensive and mechanised mode. As such a course has been developed to provide latest knowledge and updated account of modern production systems enhancing overall productivity.

V. Aim of the course

To keep abreast with latest developments and trends in production technologies of tropical, subtropical and temperate fruits.

The course structure is as follows:-

No.	Blocks	Units
1	Introduction	General Concepts and Current Scenario
2	Advanced Technologies	Propagation, Planting Systems and Crop Regulation
3	Management Practices	Overcoming Stress and Integrated Approaches

VI. Theory

Block 1: Introduction

Unit I: General Concepts and Current Scenario: National and International scenario, national problems.

Block 2: Advanced Technologies

Unit I: Propagation, Planting Systems and Crop Regulation: Recent advances in propagation – root stocks, planting systems, High density planting, crop modeling, Precision farming, decision support systems – aspects of crop regulation- physical and chemical regulation.

Block 3: Management Practices

Unit I: Overcoming Stress and Integrated Approaches: Effects on physiology and development, influence of stress factors, strategies to overcome stress effects, integrated and modern approaches in water and nutrient management, Physiological disorders, Total quality management (TQM) – Current topics.

Crops

Mango, Banana, Grapes, Citrus, Papaya, Litchi, Guava, Pomegranate, Apple, Pear, Peach, Plum, Apricot, Cherry, Almond, Walnut, Pecan, Strawberry, Kiwifruit.

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

After the successful completion of the course, the students would have

- Updated knowledge on current trends in fruit production.

IX. Suggested Reading

Bartholomew DP, Paull RE and Rohrbach KG. eds. 2002. *The Pineapple: Botany, Production, and Uses*. CAB International.

Bose TK, Mitra SK and Sanyol D. Eds. 2002. *Fruits of India – Tropical and Sub- Tropical*. 3rd Ed. Vols. I, II. Naya Udyog, Kolkata, India.

Dhillon WS and Bhatt ZA. 2011. *Fruit Tree Physiology*. Narendra Publishing House, New Delhi.

Dhillon WS. 2013. *Fruit Production in India*. Narendra Publishing House, New Delhi.

Gowen S. 1995. *Bananas and Plantains*. Chapman & Hall Publication, US.

Litz RE. ed. 2009. *The Mango: Botany, Production and Uses*. CAB International.

Peter KV. 2016. *Innovations in Horticulture*. NIPA, New Delhi.

Robinson JC and Saúco VG. 2010. *Bananas and Plantains* (Vol. 19). CAB International.

Samson JA. 1980. *Tropical Fruits*. Longman, USA.

Sharma RR and Krishna H. 2014. *Fruit Production: Major Fruits*. Daya Publishing House, Delhi.
Singh S, Shivankar VJ, Srivastava AK and Singh IP. 2004. *Advances in Citriculture*. Jagmander Book Agency, New Delhi.
Stover RH and Simmonds NW. 1991. *Bananas*. Longman, USA.
Chadha KL, Ahmed N, Singh SK and Kalia P. 2016. *Temperate Fruits and Nuts- Way Forward for Enhancing Production and Quality*.Daya Publishing House, New Delhi.
Childers NF, Morris JR and Sibbett GS. 1995. *Modern Fruit Science: Orchard and Small Fruit Culture*. Horticultural Publications, USA.
Erez A. 2013. *Temperate Fruit Crops in Warm Climates*. Springer Science.
Jackson D, Thiele G, Looney NE and Morley-Bunker M. 2011. *Temperate and Subtropical Fruit Production*. CAB International.
Ryugo K. 1998. *Fruit Culture: Its Science and Art*. John Wiley & Sons, USA.
Tromp J, Webster AS and Wertheim SJ. 2005. *Fundamentals of Temperate Zone Tree Fruit Production. Backhuys Publishers,* Lieden, The Netherlands.
Westwood MN. 2009. *Temperate Zone Pomology: Physiology and Culture*. 3rdEdn. Timber Press, USA.

I. Course Title : Recent Developments in Growth Regulation
II. Course Code : FSC 603
III. Credit Hours : (3+0)

IV. Why this course ?

Technological advancements have resulted in deeper understanding of growth and developmental processes in plants. There is equal and just need to apply these in fruit crops for harnessing maximum benefits in term of yield and quality. So a course has been designed to provide latest information on physiological and biochemical aspects of growth and development.

V. Aim of the course

To develop updates on recent advances in growth regulation of fruit crops.

Structure of the course is as under:

No.	Blocks	Units
1	Introduction	Current Concepts and Principles
2	Growth Substances	Phytohormones and Growth Regulators
3	Growth and Development	Regulation of Developmental Processes

VI. Theory

Block 1: Introduction

Unit I: Current Concepts and Principles: Eco-physiological influences on growth and development of fruit crops-flowering, fruit set- Crop load and assimilate partitioning and distribution.

Block 2: Growth Substances

Unit I: Phytohormones and Growth Regulators: Root and canopy regulation, study of plant growth regulators in fruit culture- structure, biosynthesis, metabolic and morphogenetic effects of different plant growth promoters and growth retardants. Absorption, translocation and degradation of phytohormones – internal and external factors influencing hormonal synthesis, biochemical action, growth promotion and inhibition, canopy management for fertigated orchards.

Block 3: Growth and Development

Unit I: Regulation of Developmental Processes: Growth regulation aspects of propagation, embryogenesis, seed and bud dormancy, fruit bud initiation, regulation of flowering, off season production.

Flower drop and thinning, fruit-set and development, fruit drop, parthenocarpy, fruit maturity and ripening and storage, molecular approaches in crop growth regulation- current topics.

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

After the successful completion of the course, the students would have

- Complete understanding of growth dynamics in various fruit crops
- Know-how on manipulation of growth and development processes.

IX. Suggested Reading

Bhatnagar P. 2017. *Physiology of Growth and Development of Horticultural Crops*. Agrobios (India).

Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. John Wiley & Sons, US.

Fosket DE. 1994. *Plant Growth and Development: A Molecular Approach*. Academic Press, USA.

Leopold AC and Kriedermann PE. 1985. *Plant Growth and Development*. 3rd Ed. McGraw-Hill, US.

Richard N. Arteca. 1995. *Plant Growth Substances – Principles and Applications*. Chapman & Hall, USA.

Roberts J, Downs S and Parker P. 2002. *Plant Growth Development*. In: *Plants* (I. Ridge, Ed.), Oxford University Press.

Salisbury FB and Ross CW. 1992. *Plant Physiology*. 4th Ed. Wadsworth Publication.

I. Course Title : Advanced Laboratory Techniques

II. Course Code : FSC 604

III. Credit Hours : (1+2)

IV. Why this course ?

Accurate quality analysis of edible fruit commodities warrants stringent measurement protocols besides requisite instruments/ tools and laboratory facilities. Consequently, a specialised course is designed for imparting basic and applied training on physical and biochemical assessment of the horticultural produce.

V. Aim of the course

To familiarize with the laboratory techniques for analysis of fruit crops.

The organisation of the course is as under:-

No.	Blocks	Units
1	General Aspects	I Safety Measures and Laboratory Maintenance
2	Qualitative and Quantitative Analysis	I Destructive and Non-destructive Analysis Methods II Chromatographic and microscopic Analysis III Sensory Analysis

VI. Theory

Block 1: General Aspects

Unit 1: Safety Measures and Laboratory Maintenance: Safety aspects and upkeep of laboratory, sampling procedures for quantitative analysis, determination of proximate composition of horticultural produce. Standard solutions, determination of relative water content (RWC), physiological loss in weight (PLW), calibration and standardization of instruments, textural properties of harvested produce, TSS, Specific gravity, pH and acidity.

Block 2: Qualitative and Quantitative Analysis

Unit I: Destructive and Non-destructive Analysis Methods: Refractometry, spectrophotometry, non-destructive determination of colour, ascorbic acid, sugars, and starch in food crops.

Unit II: Chromatographic and Microscopic Analysis: Basic chromatographic techniques, GC, HPLC, GCMS, Electrophoresis techniques, ultra filtration. Application of nuclear techniques in harvested produce. Advanced microscopic techniques, ion leakage as an index of membrane permeability, determination of biochemical components in horticultural produce.

Unit III: Sensory Analysis: Importance of ethylene, quantitative estimation of rate of ethylene evolution, using gas chromatograph (GC). Sensory analysis techniques, control of test rooms, products and panel.

VII. Practical

- Determination of moisture, relative water content and physiological loss in weight (2)
- Determination of biochemical components in horticultural produce (3);
- Calibration and standardization of instruments (1);
- Textural properties of harvested produce (1);
- Determination of starch index (SI) (1);
- Specific gravity for determination of maturity assessment, and pH of produce (1)
- Detection of adulterations in fresh as well as processed products (2)
- Non-destructive determination of colour, ascorbic acid, vitamins, carotenoids, sugars and starch (2)
- Estimation of rate of ethylene evolution using gas chromatograph (GC) (2)
- Use of advanced microscopes (fluorescent, scanning electron microscope, phase contrast, etc.) (2)

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The students would be expected to develop skills and expertise on:
- Upkeep of laboratories and handling of research instruments
- Principles and methods of various analysis

X. Suggested Reading

AOAC International. 2003. *Official Methods of Analysis of AOAC International*. 17th Ed. Gaithersburg, MD, USA, Association of Analytical Communities, USA.
Clifton M and Pomeranz Y. 1988. *Food Analysis-Laboratory Experiments*. AVI Publication, USA.
Leo ML. 2004. *Handbook of Food Analysis*. 2nd Ed. Vols. I-III, USA.
Linskens HF and Jackson JF. 1995. *Fruit Analysis*. Springer.
Pomrenz Y and Meloan CE. 1996. *Food Analysis – Theory and Practice*. CBS, USA.
Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. 2nd Ed. Tata-McGraw-Hill, New Delhi.
Thompson AK. 1995. *Post Harvest Technology of Fruits and Vegetables*. Blackwell Sciences. USA.

I. Course Title : Arid and Dryland Fruit Production

II. Course Code : FSC 605

III. Credit Hours : (2+0)

IV. Why this course ?

Arid and dryland regions are known for growing an array of delicious and nutritious fruits (e.g. date palm, aonla, ber etc). Over the years, notable progress has been made in respect of domestication and technological advancements. Thus a course has been developed.

V. Aim of the course

To keep abreast with latest developments and trends in production technology of arid and dryland fruit crops.

The course is organised as under:-

No.	Blocks	Units
1	Introduction	General Concepts and Current Scenario
2	Advanced Technologies	Propagation, Planting Systems and Crop Regulation
3	Management Practices	Stress Mitigation and Integrated Approaches

VI. Theory

Block 1: Introduction

Unit I: General Concepts and Current Scenario: Characteristics features and major constraints of the arid and dryland region, distinguishing features of the fruit species trees for adaptation in adapting to the region, nutritional and pharmaceutical importance, national problems.

Block 2: Advanced Technologies

Unit I: Propagation, Planting Systems and Crop Regulation: Recent advances in propagation – root stocks, planting systems, High density planting, crop modelling, Precision farming, decision support systems – aspects of crop regulation- physical and chemical regulation, effects on physiology and development, influence of stress factors.

Block 3: Management Practices

Unit I: Stress Mitigation and Integrated Approaches: Strategies to overcome stress effects, integrated and modern approaches in water and nutrient management, total quality management (TQM) – Current topics.

Crops

Aonla, Annonas, ber, bael, jamun, date palm, cactus pear, khejri, kair, pilu, lasoda, manila, tamarind, monkey jack, mahua, khirni, amra, seabuckthorn, chilgoza, cafel, rhododendron, box myrtle, chironji, phalsa, karonda,woodapple, paniala and other minor fruits of regional importance

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

Consequent upon successful completion of the course, the students are expected to learnt about

- Fruit crops adopting to arid and drylands and their features
- Specific cultivation and management practices

IX. Suggested Reading

Hiwale S. 2015. *Sustainable Horticulture in Semiarid Drylands*. Springer.

Krishna H and Sharma RR. 2017. *Fruit Production – Minor Fruits*.Daya Publishing House, Delhi.

More T A, Singh RS, Bhargava R and Sharma BD. 2012. *Arid Horticulture for Nutrition and Livelihood*. Agrotech Publishing Academy, Udaipur (Rajasthan).

Pareek OP, Sharma S and Arora RK. 2007. *Underutilised Edible Fruits and Nuts,* IPGRI, Rome.

Peter K.V. 2010. *Underutilized and Underexploited Horticultural Crops*. NIPA, New Delhi.

Saroj PL, Dhandar DG and Vashishta BB. 2004. *Advances in Arid Horticulture*, Vol.-1 *Present Status*. IBDC, Lucknow.

Saroj P L and Awasthi OP. 2005. *Advances in Arid Horticulture*, Vol: II: *Production Technology of Arid and Semiarid Fruits*. IBDC, Lucknow.

Sontakke MB. 2014. *Production and Management of Fruit crops in Arid/ Drylands*. Agrotech Publishing Academy, Udaipur (Rajasthan).

I. Course Title : Abiotic Stress Management in Fruit Crops

II. Course Code : FSC 606

III. Credit Hours : (2+1)

IV. Why this course ?

Low soil fertility coupled with unpredictable and unfavourable environments often result in stress conditions. Non-availability of optimum level of inputs and congenial weather necessitates the development of suitable management practices to overcome various abiotic stresses. Hence a course is customized.

V. Aim of the course

To updates knowledge on recent trends in management of abiotic stresses in fruit crops.

The course is organised as follows:

No.	Blocks	Units
1	Introduction	Basic Aspects and Principles
2	Stress Impact	Assessment, Physiology and Performance
3	Stress Management	Mitigation Measures and Conservation Practices

VI. Theory

Block 1: Introduction

Unit I: Basic Aspects and Principles: Stress – definition, classification, stresses due to water (high and low), temperature (high and low), radiation, wind, soil conditions (salinity, alkalinity, ion toxicity, fertilizer toxicity, etc.). Pollution – increased level of CO_2, industrial wastes, impact of stress in fruit crop production, stress indices, physiological and biochemical factors associated with stress, fruit crops suitable for different stress situations.

Block 2: Stress Impact

Unit I: Assessment, Physiology and Performance: Crop modeling for stress situations, cropping systems, assessing the stress through remote sensing, understanding adaptive features of crops for survival under stress, interaction among different stresses and their impact on crop growth and productivity.

Block 3: Stress Management

Unit I: Mitigation Measures and Conservation Practices: Greenhouse effect and methane emission and its relevance to abiotic stresses, use of anti transpirants and PGRs in stress management, mode of action and practical use, HSP inducers in stress management techniques of soil moisture conservation, mulching, hydrophilic polymers. Rain water harvesting, increasing water use efficiency, skimming technology, contingency planning to mitigate different stress situations, stability and sustainability indices.

VII. Practical

- Seed treatment/ hardening practices (2);
- Container seedling production (2);
- Analysis of soil moisture estimates (FC, ASM, PWP) (1);
- Analysis of plant stress factors, RWC, chlorophyll flourosence, chlorophyll stability index, ABA content, plant waxes, stomatal diffusive resistance, transpiration, photosynthetic rate, etc. under varied stress situations (5);
- Biological efficiencies, WUE, solar energy conversion and efficiency (2);
- Crop growth sustainability indices and economics of stress management (2);
- Visit to orchards and watershed locations (2);

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

XI. Learning outcome

On successful completion of the course, the students are expected to generate know-how on

- Various types of abiotic stresses and their effects
- Physiological processes underlying abiotic stresses
- Management and conservation practices to overcome stress

X. Suggested Reading

Blumm A. 1988. *Plant Breeding for Stress Environments*. CRC Publication, USA. Christiansen, MN and Lewis CF. 1982. *Breeding Plants for Less Favourable Environments*. Wiley International Science, USA.

Kanayama Y and Kochetor. 2015. *Abiotic Stress Biology in Horticultural Plants*. Springer.

Kramer PJ. 1980. *Drought Stress and the Origin of Adaptation*. In: *Adaptation of Plants to Water and High Temperature Stress*. John Wiley & Sons, USA.

Maloo SR. 2003. *Abiotic Stress and Crop Productivity*. Agrotech Publ. Academy, India.

Nickell LG. 1983. *Plant Growth Regulating Chemicals*. CRC Publication, USA.

Rao NKS, Shivashankar KS and Laxman RH. 2016. *Abiotic Stress Physiology of Horticultural Crops*. Springer.

Turner NC and Kramer PJ. 1980. *Adaptation of Plants to Water and High Temperature Stress*. John Wiley & Sons, USA.

I. Course Title : Biodiversity and Conservation of Fruit Crops

II. Course Code : FSC 607

III. Credit Hours : (2+1)

IV. Why this course ?

The availability of pertinent gene pool is of utmost importance to mitigate adverse climate and to counter diseases and pests. In addition, specific gene sources (germplasm) would always be a necessity to develop superior genotypes. Considering the importance of conserving biodiversity in fruit crops for future use, the course has been designed.

V. Aim of the course

To understand the status and magnitude of biodiversity and strategies in germplasm conservation of fruit crops.

The course is organised as follows:-

No.	Blocks	Units
1	General Aspects	Issues, Goals and Current Status
2	Germplasm Conservation	Collection, Maintenance and Characterization
3	Regulatory Horticulture	Germplasm Exchange, Quarantine and Intellectual Property Rights

VI. Theory

Block 1: General Aspects

Unit I: Issues, Goals and Current Status: Biodiversity and conservation; issues and goals- needs and challenges; present status of gene centres; world's major centres of fruit crop domestication; current status of germplasm availability/ database of fruit crops in India.

Block 2: Germplasm Conservation

Unit I: Collection, Maintenance and Characterization: Exploration and collection of germplasm; sampling frequencies; size and forms of fruit and nut germplasm collections; active and base collections.Germplasm conservation- *in situ* and *ex situ* strategies, on farm conservation; problem of recalcitrancy- cold storage of scions, tissue culture, cryopreservation, pollen and seed storage.

Block 3: Regulatory Horticulture

Unit I: Germplasm Exchange, Quarantine and Intellectual Property Rights: Regulatory horticulture, inventory and exchange of fruit and nut germplasm, plant quarantine, phyto-sanitary certification, detection of genetic constitution of germplasm and maintenance of core collection. IPRs, Breeder's rights, Farmer's rights, PPV and FR Act.

GIS and documentation of local biodiversity, Geographical indications, GIS application in horticultural mapping and spatial analyses of field data; benefits of GI protection; GI tagged fruit varieties in India.

VII. Practical

- Documentation of germplasm- maintenance of passport data and other records of accessions (2);
- Field exploration trips and sampling procedures (2);
- Exercise on *ex situ* conservation – cold storage, pollen/ seed storage (2);
- Cryopreservation (2);
- Visits to National Gene Bank and other centers of PGR activities (2);
- Detection of genetic constitution of germplasm (2);
- Germplasm characterization using a standardised DUS test protocol (2);
- Special tests with biochemical and molecular markers (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The student would be expected to learn about the significance of germplasm and various strategies to conserve it in the present context.

X. Suggested Reading

Dhillon BS, Tyagi RK, Lal A and Saxena S. 2004. *Plant Genetic Resource Management. – Horticultural Crops.*Narosa Publishing House, New Delhi.

Engles JM, Ramanath RV, Brown AHD and Jackson MT. 2002. *Managing Plant Genetic Resources,* CABI, Wallingford, UK.
Frankel OH and Hawkes JG. 1975. *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press, USA.
Hancock J. 2012. *Plant Evolution and the Origin of Crops Species*. CAB International.
Jackson M, Ford-Lloyd B and Parry M. 2014. *Plant Genetic Resources and Climate Change.* CABI, Wallingford, UK.
Moore JN and Ballington Jr, JR. 1991. *Genetic Resources of Temperate Fruit and Nut Crops.* ISHS, Belgium.
Peter KV. 2008. *Biodiversity of Horticultural Crops*. Vol. II. Daya Publ. House, Delhi.
Peter KV. 2011. *Biodiversity in HorticulturalCrops*.Vol.III. Daya Publ. House, Delhi.
Rana JC and Verma VD. 2011. *Genetic Resources of Temperate Minor Fruits (Indigenous and Exotic)*. NBPGR, New Delhi.
Rajasekharan PE, Rao V and Ramanatha V. 2019. *Conservation and Utilization of Horticultural Genetic Resources*. Springer.
Sthapit B, *et al*. 2016. *Tropical Fruit Tree Diversity (Good Practices for in situ and ex situ conservation*). Bioversity International. Routledge, Taylor and Francis Group.
Virchow D. 2012. *Conservation of Genetic Resources*, Springer Verlag, Berlin.

I. Course Title : Smart Fruit Production

II. Course Code : FSC 608

III. Credit Hours : (2+0)

IV. Why this course ?

In the era of automation and mechanization, several recent innovations have direct applications in fruit growing. Thus a need is felt to have course on smart innovations.

V. Aim of the course

To acquire knowledge on hi-tech innovations useful in fruit crops.

The course is structure is as under:

No.	Blocks	Units
1	Introduction	Importance and Overview
2	Crop Modelling and Forecasting	GIS, Sensors and Wireless System
3	Nanotechnology	Concepts and Methods
4	Innovative Approaches	Mechanization, Automation and Robotics

VI. Theory

Block 1: Introduction

Unit I: Importance and Overview: Introduction and importance; concepts and applications of artificial intelligence systems; case studies in horticulture

Block 2: Crop Modelling and Forecasting

Unit I: GIS, Sensors and Wireless Systems: Application of sensors in fruit production, crop monitoring – crop load and stress incidence forecast modules, remote sensing, Geographical Information System (GIS), Differential Geo-Positioning System (DGPS) hi-tech nursery production of fruit crops under protected conditions, ultra modern wireless based drip irrigation network.

Block 3: Nanotechnology

Unit I: Concepts and Methods: Nanotechnology for smart nutrient delivery in fruit farming, concepts and methods, practical utility, nano-fertilizers, nano-herbicides; nano-pesticides

Block 4: Innovative Approaches

Unit I: Mechanization, Automation and Robotics: Production systems amenable to automation and mechanization; automated protected structures (turn-key systems); hydroponics, aeroponics, bioreactors for large scale plant multiplication; Use of drones and robotics in fruit growing – robotic planters, sprayers, shakers, harvesters, stackers, etc. Visit to Hi-tech facilities.

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

After successful completion of the course, the students are expected to learn about latest innovations in automation, nanotechnology and robotics for realising smart fruit production.

IX. Suggested Reading

Chadha *et al*. 2017. *Doubling Farmers Incomes through Horticulture*. Daya Publishing House, New Delhi.

Chadha *et al*. 2019.*Shaping the Future of Horticulture*. Kruger Brentt Publishers, UK.

Hewett EW. 2013. *Automation, Mechanization and Robotics in Horticulture*. *In:* Workshop on Emerging Postharvest Technologies. UC, Davis, USA.

Peter KV. 2016. *Innovations in Horticulture*. NIPA, New Delhi.

Prasad S, Singh D and Bhardwaj RL. 2012. *Hi-Tech Horticulture*.Agrobios (India).

Tyagi, S. 2019. *Hi- Tech Horticulture*. Vols. 1 to 7. NIPA, New Delhi.

Zhang Q. 2017. *Automation in Tree Fruit production – Principles and Practice*. CABI.

http://horticulture.ucdavis.edu- Innovative Technology for Horticultural Department.

Selected Journals

Sr. No.	Name of the Journal	ISSN No.
1.	*Advances in Horticultural Science*	0394-6169
2.	*Acta Horticulturae*	0567-7572
3.	*American Journal of Enology and Viticulture*	0002-9254
4.	*Annals of Arid Zone*	0570-1791
5.	*Annals of Horticulture*	0974-8784
6.	*Biodiversity and Conservation*	0960-3115
7.	*Current Horticulture*	2347-7377
8.	*European Journal of Horticultural Science (Gartenbauwissenschaft)*	1611-4426
9.	*Fruits*	0248-1294
10.	*Genetic Resources and Crop Evolution*	0925-9864
11.	*Horticultural Plant Journal*	2488-0141
12.	*Horticulture Environment and Biotechnology*	2211-3452
13.	*HortScience*	0018-5345
14.	*Indian Horticulture Journal*	2249-6823
15.	*Indian Journal of Arid Horticulture*	Naas-1234
16.	*Indian Journal of Dryland Agricultural Research and Development*	0971-2062

Sr. No.	Name of the Journal	ISSN No.
17.	*Indian Journal of Horticulture*	0972-8538
18.	*International Journal of Fruit Science*	1553-8621
19.	*International Journal of Horticulture*	1927-5803
20.	*International Journal of Innovative Horticulture*	2320-0286
21.	*Journal of Applied Horticulture*	0972-1045
22.	*Journal of Horticultural Research*	2300-5009
23.	*Journal of Horticultural Science and Biotechnology (Journal of Horticultural Science, England)*	1462-0316
24.	*Journal of Horticultural Sciences*	0973-354X
25.	*Journal of Horticulture*	2376-0354
26.	*Journal of The American Society for Horticultural Science*	0003-1062
27.	*Journal of Tree Fruit Production*	1055-1387
28.	*New Zealand Journal of Crop and Horticultural Science*	0114-0671
29.	*Progressive Horticulture*	0970-3020
30.	*Scientia Horticulturae*	0304-4238
31.	*The Asian Journal of Horticulture*	0973-4767
32.	*The Journal of American Pomological Society*	1527-3741

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Horticultural Sciences
– Vegetable Science

Preamble

(Vegetable Science)

Vegetables are important constituents of Indian diet and play an important role ensuring nutritional security. They are generally of short duration, high yielding, nutraceuitically rich, economically viable and generating substancial on-farm and off-farm employment. Vegetables have aprestine place in Indian agricultural economy. The country is being blessed with diverse agro-climatic conditions ranged from the tempearate to arid more than 60 cultivated and 30 lesser known vegetables are being grown.

The country has witnessed a tremendous growth in vegetable production and productivity as a result of improved varieties/ F1 hybrids/ technologies through systematic research coupled with their large scale adoption by the farmers and developmental policies of government compared to area (2.84 m ha), production (16.5 mt) and productivity (5.8 t/ha) in 1950–51 there had been phenomenal increase in area (>3 folds; 10.1 m ha), production (>10 folds; 185 mt) and productivity (>3 folds; 18.0 t/ha) during 2017–18. Increasing per capita income, health conciousness, urbanisation, shifting of farmers to high value vegetables due to higher income, favourable income elasticity of demand and annual growth rate of domestic demand for vegetables are also important factors fueling its growth in the country.

During 2016–17, the total exports including potato and onion accounted for ₹ 5,922 crores sharing 35% of total horticultural exports. With the current level of vegetable production in the country (171 mt), population (1.3 billion) and considering 25% post harvest losses and 5% export and processing, the per capita availability of vegetable production in our country is 250 g as against 300 g recommended dietary allowance (RDA). With projected population of 1.45 billion by 2030, India has to produce 210 mt of vegetables. The targeted production needs to be achieved through utilizing scientific technological and traditional strength in a sustainable manner without much increasing area under vegetables.

Looking in to the above scenario in vegetable production, there is a need to update the knowledge among the post-graduates of Vegetable Science. An effort is therefore made to encompass the adavances made in the vegetable production by revisting the post-graduate curriculum for delivering and assuring quality education. The proposed curriculum aims to develop a competent human resource equipped with holistic and updated knowledge and skill in the field of Vegetable Science.

The course curriculum has been restructured to cover the current requirement of vegetable production and post harvest management to increase capabilities of students. In order to accomplish the task, either new courses have been formulated or existing course contents are upgraded to include latest developments in vegetables production.

In line with national policies, the existing course contents have been upgraded and five new courses, viz., Principles of vegetable breeding, Breeding for special triats in Vegetable crops, Biodiversity and conservation of Vegetable crops, Biotechnological approaches in Vegetable crops and Advanced laboratotory techniques for vegetable crops have been added. A course on Vegetable Breeding has been divided into two courses one for self-pollinated crops and another for cross pollinated vegetable crops. New components, viz., hydroponics, aeroponics, grafting technique and precision farming have been added in appropriate courses. The overall upgradation of course contents as well as addition of courses are in line with national policy priorities like doubling of farmer's income, more crop per drop, jaivik krishi, soil health, skill development, entrepreneurship development, startup initiatives, etc.

Course Title with Credit Load
M.Sc. (Hort.) in Vegetable Science

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
VSC 501*	Production of Cool Season Vegetable Crops	2+1
VSC 502*	Production of Warm Season Vegetable Crops	2+1
VSC 503*	Growth and Development of Vegetable Crops	2+1
VSC 504*	Principles of Vegetable Breeding	3+0
VSC 505	Breeding of Self Pollinated Vegetable Crops	2+1
VSC 506	Breeding of Cross Pollinated Vegetable Crops	2+1
VSC 507	Protected Cultivation of Vegetable Crops	1+1
VSC 508	Seed Production of Vegetable Crops	2+1
VSC 509	Production of Underutilized Vegetable Crops	2+1
VSC 510	Systematics of Vegetable Crops	1+1
VSC 511	Organic Vegetable Production	1+1
VSC 512	Production of Spice Crops	2+1
VSC 513	Processing of Vegetable	1+1
VSC 514	Postharvest Management of Vegetable Crops	2+1
	Minor Courses	08
	Supporting Courses	06
	Common compulsory courses	05
VSC 591	Seminar	0+1
VSC 599	Research	0+30
	Total Credits	**70**

*Compulsory among major courses

Course Contents
M.Sc. (Hort.) in Vegetable Science

I. Course Title : Production of Cool Season Vegetable Crops

II. Course Code : VSC 501

III. Credit Hours : (2+1)

IV. Why this course ?

Cool season vegetables are a major source of dietary fibres, minerals and vitamins. Some of these vegetables also contribute protein, fat and carbohydrate. Most of the leafy and root vegetables are rich in minerals, especially in micro-elements such as copper, manganese and zinc. Vegetables differ in their temperature requirement for proper growth and development. Most of the winter vegetable crops are cultivated in cool season when the monthly mean temperature does not exceed 21°C. Even in temperate climate, these vegetables are cultivated in spring summer in hilly tracks where the daytime temperature in summer is less than 21°C. The students of vegetable science need to have an understanding of production technology of important cool season vegetable crops and their management.

V. Aim of the course

To impart knowledge and skills on advancement in production technology of cool season vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Production of cool season vegetable crops	I Bulb and tuber crops II Cole crops III Root crops IV Peas and beans V Leafy vegetables

VI. Theory

Introduction, commercial and nutritional importance, origin and distribution, botany and taxonomy, area, production, productivity and constraints, soil requirements, climatic factors for yield and quality, commercial varieties/ hybrids, seed rate and seed treatment, raising of nursery, sowing/ planting time and methods,hrydroponics and aeroponics, precision farming, cropping system, nutritional including micronutrients and irrigation requirements, intercultural operations, special horticultural practices, weed control, mulching, role of plant growth regulators, physiological disorders, maturity indices, harvesting, yield, post-harvest management (grading, packaging and marketing), pest and disease management and production economics of crops.

Unit I

Bulb and tuber crops—Onion, garlic and potato.

Unit II

Cole crops—Cabbage, cauliflower, kohlrabi, broccoli, Brussels sprouts and kale.

Unit III

Root crops—Carrot, radish, turnip and beetroot.

Unit IV

Peas and beans—Garden peas and broad bean.

Unit V

Leafy vegetables—Beet leaf, fenugreek, coriander and lettuce.

VII. Practical

- Scientific raising of nursery and seed treatment;
- Sowing and transplanting;
- Description of commercial varieties and hybrids;
- Demonstration on methods of irrigation, fertilizers and micronutrients application;
- Mulching practices, weed management;
- Use of plant growth substances in cool season vegetable crops;
- Study of nutritional and physiological disorders;
- Studies on hydroponics, aeroponics and other soilless culture;
- Identification of important pest and diseases and their control;
- Preparation of cropping scheme for commercial farms;
- Visit to commercial farm, greenhouse/ polyhouses;
- Visit to vegetable market;
- Analysis of benefit to cost ratio.

VIII. Teaching Methods/ Activities

- Classroom lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of cool season vegetable crops in India
- Acquire knowledge about the production technology and post-harvest handling of cool season vegetable crops
- Calculate the economics of vegetable production in India

X. Suggested Reading

Bose TK, Kabir J, Maity TK, Parthasarathy VA and Som MG. 2003. *Vegetable crops*. Vols. I-III. Naya udyog.

Bose TK, Som MG and Kabir J. (Eds.). 1993. *Vegetable crops*. Naya prokash.

Chadha KL and Kalloo G. (Eds.). 1993-94. *Advances in horticulture* Vols. V-X. Malhotra publ. house.

Chadha KL. (Ed.). 2002. *Hand book of horticulture*. ICAR.

Chauhan DVS. (Ed.). 1986. *Vegetable production in India*. Ram prasad and sons.

Fageria MS, Choudhary BR and Dhaka RS. 2000. *Vegetable crops: production technology*. Vol. II. Kalyani publishers.

Gopalakrishanan TR. 2007. *Vegetable crops*. New India publ. agency.

Hazra P and Banerjee MK and Chattopadhyay A. 2012. *Varieties of vegetable crops in India*, (Second edition), Kalyani publishers, Ludhiana, 199 p.
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Saini GS. 2001. *A text book of oleri and flori culture*. Aman publishing house.
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I. Course Title : Production of Warm Season Vegetable Crops

II. Course Code : VSC 502

III. Credit Hours : (2+1)

IV. Why this course ?

Unlike cool-season vegetables, warm-season vegetable crops require higher soil and air temperature, thus, they are always planted after the last frost date ranging from late spring after the last frost date to late summer. Daytime temperature may still be warm enough but drop so much at night-time that the weather is not suitable for warm-season crops any longer. In general summer vegetables require a little higher temperature than winter vegetables for optimum growth. In summer vegetables, the edible portion is mostly botanical fruit. The students of vegetable science need to have an understanding of production technology of important warm season vegetable crops and thereafter their management.

V. Aim of the course

To impart knowledge and skills on advancement in production technology of warm season vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Production of warm season vegetable crops	1. Fruit vegetables 2. Beans 3. Cucurbits 4. Tuber crops 5. Leafy vegetables

VI. Theory

Introduction, commercial and nutritional importance, origin and distribution, botany and taxonomy, area, production, productivity and constraints, soil requirements, climatic factors for yield and quality, commercial varieties/ hybrids, seed rate and seed treatment, raising of nursery including grafting technique, sowing/ planting time and methods, precision farming, cropping system, nutritional including micronutrients and irrigation requirements, intercultural operations, special horticultural practices namely hydroponics, aeroponics, weed control, mulching, role of plant growth regulators, physiological disorders, maturity indices, harvesting, yield, post-harvest management (grading, packaging and marking), pest and disease management and economics of crops.

Unit I

Fruit vegetables—Tomato, brinjal, hot pepper, sweet pepper and okra.

Unit II

Beans—French bean, Indian bean (Sem), cluster bean and cowpea.

Unit III

Cucurbits—Cucumber, melons, gourds, pumpkin and squashes.

Unit IV

Tuber crops—Sweet potato, elephant foot yam, tapioca, taro and yam.

Unit V

Leafy vegetables—Amaranth and drumstick.

VII. Practical

- Scientific raising of nursery and seed treatment;
- Sowing, transplanting, vegetable grafting;
- Description of commercial varieties and hybrids;
- Demonstration on methods of irrigation, fertilizers and micronutrients application;
- Mulching practices, weed management;
- Use of plant growth substances in warm season vegetable crops;
- Study of nutritional and physiological disorders;
- Studies on hydroponics, aeroponics and other soilless culture;
- Identification of important pest and diseases and their control;
- Preparation of cropping scheme for commercial farms;
- Visit to commercial farm, greenhouse/ polyhouses;
- Visit to vegetable market;
- Analysis of benefit to cost ratio.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of warm season vegetable crops in India
- Acquire knowledge about the production technology and post-harvest handling of warm season vegetable crops
- Calculate the economics of vegetable production in India

Suggested Reading

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Chadha KL. (Ed.). 2002. *Hand book of horticulture*. ICAR.

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I. Course Title : Growth and Development of Vegetable Crops

II. Course Code : VSC 503

III. Credit Hours : (2+1)

IV. Why this course ?

In agriculture, the term plant growth and development is often substituted with crop growth and yield since agriculture is mainly concerned with crops and their economic products. Growth, which is irreversible quantitative increase in size, mass, and/ or volume of a plant or its parts, occurs with an expenditure of metabolic energy. Plant development is an overall term, which refers to various changes that occur during its life cycle. In vegetable crops, development is a series of processes from the initiation of growth to death of a plant or its parts. Growth and development are sometimes used interchangeably in conversation, but in a botanical sense, they describe separate events in the organization of the mature plant body. The students of vegetable science need to have an understanding of growth and development of vegetable crops.

V. Aim of the course

To teach the physiology of growth and development of vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Growth and development of vegetable crops	1. Introduction and phytohormones 2. Physiology of dormancy and germination 3. Abiotic factors 4. Fruit physiology 5. Morphogenesis and tissue culture

VI. Theory

Unit I

Introduction and phytohormones—Definition of growth and development; Cellular structures and their functions; Physiology of phyto-hormones functioning/ biosynthesis and mode of action; Growth analysis and its importance in vegetable production.

Unit II

Physiology of dormancy and germination—Physiology of dormancy and germination of vegetable seeds, tubers and bulbs; Role of auxins, gibberellilns, cyktokinins and abscissic acid; Application of synthetic PGRs including plant growth retardants and inhibitors for various purposes in vegetable crops; Role and mode of action of morphactins, antitranspirants, anti-auxin, ripening retardant and plant stimulants in vegetable crop production.

Unit III

Abiotic factors—Impact of light, temperature, photoperiod, carbon dioxide, oxygen and other gases on growth, development of underground parts, flowering and sex expression in vegetable crops; Apical dominance.

Unit IV

Fruit physiology—Physiology of fruit set, fruit development, fruit growth, flower and fruit drop; parthenocarpy in vegetable crops; phototropism, ethylene inhibitors, senescence and abscission; fruit ripening and physiological changes associated with ripening.

Unit V

Morphogenesis and tissue culture—Morphogenesis and tissue culture techniques in vegetable crops; Grafting techniques in different vegetable crops.

VII. Practical

- Preparation of plant growth regulator’s solutions and their application;
- Experiments in breaking and induction of dormancy by chemicals;
- Induction of parthenocarpy and fruit ripening;
- Application of plant growth substances for improving flower initiation, changing sex expression in cucurbits and checking flower and fruit drops and improving fruit set in solanaceous vegetables;
- Growth analysis techniques in vegetable crops;
- Grafting techniques in tomato, brinjal, cucumber and sweet pepper.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)

- Student presentation
- Hands on training of different procedure
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire knowledge about the growth and development of plants in vegetable crops
- Distinguish between primary and secondary growth in plant stems
- Understand how hormones affect the growth and development of vegetable crops

X. Suggested Reading

Bleasdale JKA. 1984. *Plant physiology in relation to horticulture* (2nd Edition) MacMillan.

Gupta US. Eds. 1978. *Crop physiology*. Oxford and IBH, New Delhi.

Kalloo G. 2017. *Vegetable grafting: Principles and practices*. CAB International

Krishnamoorti HN. 1981. *Application growth substances and their uses in agriculture*. Tata McGraw Hill, New Delhi.

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Saini *et al*. (Eds.). 2001. *Laboratory manual of analytical techniques in horticulture*. Agrobios, Jodhpur.

Wien HC. (Eds.). 1997. *The physiology of vegetable crops*. CAB International.

I. Course Title : Principles of Vegetable Breeding

II. Course Code : VSC 504

III. Credit Hours : (2+1)

IV. Why this course ?

Plant breeding has been practiced for thousands of years, since beginning of human civilization. Vegetable breeding, which is an art and science of changing the traits of plants in order to produce desired traits, has been used to improve the quality of nutrition in products for human beings. A breeding programme, which is needed if current varieties are not producing up to the capacity of the environment, can be accomplished through many different techniques ranging from simply selecting plants with desirable characteristics, make use of knowledge of genetics and chromosomes to more complex molecular techniques. When different genotypes exhibit differential responses to different sets of environmental conditions, a genotype x environment (GxE) interaction is said to occur. Breeding high yielding open pollinated varieties and hybrids, and exploitation of location specific component of genotypic performance are the only options left to reduce this increasing gap between the production and requirements in view of decreasing land resources. Noevertheless, vegetable breeding is an integral part of plant breeding but this will be re-modeled to suit to breeding of different vegetables crops. The students of vegetable science who are having breeding as major subject need to have an understanding of vegetable breeding principles.

V. Aim of the course

To teach basic principles and practices of vegetable breeding

The course is constructed given as under:

No.	Block	Unit
1.	Principles of vegetable breeding	I. Importance and history II. Selection procedures III. Heterosis breeding IV. Mutation breeding V. Polyploid breeding VI. Ideotype breeding

VI. Theory

Unit I

Importance and history- Importance, history and evolutionary aspects of vegetable breeding and its variation from cereal crop breeding.

Unit II

Selection procedures- Techniques of selfing and crossing; Breeding systems and methods; Selection procedures and hybridization; Genetic architecture; Breeding for biotic stress (diseases, insect pests and nematode), abiotic stress (temperature, moisture and salt) resistance and quality improvement; Breeding for water use efficiency (WUE) and nutrients use efficiency (NUE).

Unit III

Heterosis breeding- Types, mechanisms and basis of heterosis, facilitating mechanisms like male sterility, self-incompatibility and sex forms.

Unit IV

Mutation and Polyploidy breeding; Improvement of asexually propagated vegetable crops and vegetables suitable for protected environment.

Unit V

Ideotype breeding- Ideotype breeding; varietal release procedure; DUS testing in vegetable crops; Application of *In-vitro* and molecular techniques in vegetable improvement.

VII. Practical

- Floral biology and pollination behaviour of different vegetables;
- Techniques of selfing and crossing of different vegetables, viz., Cole crops, okra, cucurbits, tomato, eggplant, hot pepper, etc.;
- Breeding system and handling of filial generations of different vegetables;
- Exposure to biotechnological lab practices;
- Visit to breeding farms.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire knowledge about the principles of vegetable breeding
- Improve yield, quality, abiotic and biotic resistance, other important traits of vegetable crops
- Understand how the basic principles are important to start breeding of vegetable crops

X. Suggested Reading

Allard RW. 1960. *Principle of plant breeding*. John Willey and Sons, USA.

Kalloo G. 1988. *Vegetable breeding* (Vol. I, II, III). CRC Press, Fl, USA.

Kole CR. 2007. *Genome mapping and molecular breeding in plants-vegetables*. Springer, USA.

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Prohens J and Nuez F. 2007. *Handbook of plant breeding-vegetables* (Vol I and II). Springer, USA.

Singh BD. 2007. *Plant breeding- principles and methods* (8th edn.). Kalyani Publishers, New Delhi.

Singh Ram J. 2007. *Genetic resources, chromosome engineering, and crop improvement-vegetable crops* (Vol. 3). CRC Press, Fl, USA.

I. Course Title : Breeding of Self Pollinated Vegetable Crops

II. Course Code : VSC 505

III. Credit Hours : (2+1)

IV. Why this course ?

Self-pollination, which is considered the highest degree of inbreeding a plant can achieve, promotes homozygosity of all gene loci and traits of the sporophyte and restricts the creation of new gene combinations (no introgression of new genes through hybridization). The progeny of a single plant is homogeneous due to self pollination. A population of self-pollinated species comprises a mixture of homozygous lines. New genes may arise through mutation but such change is restricted to individual lines or the progenies of the mutant plant. Since a self-pollinated cultivar is generally one single genotype reproducing itself, breeding of self-pollinated species usually entails identifying one superior genotype (or a few) and its multiplication. Specific breeding methods commonly used for self-pollinated species are pure-line selection, pedigree breeding, bulk populations and backcross breeding. The students of vegetable science who take breeding as a minor subject need to have an understanding of breeding of self pollinated vegetable crops.

V. Aim of the course

To impart comprehensive knowledge about principles and practices of breeding of self pollinated vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Breeding of self pollinated vegetable crops	I. Potato II. Fruit vegetables III. Garden peas and cowpea IV. Beans V. Leafy vegetables

VI. Theory

Origin, botany, taxonomy, wild relatives, cytogenetics and genetics, types of pollination and fertilization mechanism, sterility, breeding objectives, breeding methods (introduction, selection, hybridization, mutation and polyploidy), varieties and varietal characterization, resistance breeding for biotic and abiotic stresses, breeding for protected environment and quality improvement, molecular markers and marker's assisted breeding; QTLs, PPV and FR Act.

Unit I

Tuber crops: Potato.

Unit II

Fruit vegetables- Tomato, eggplant, hot pepper, sweet pepper and okra.

Unit III

Leguminous vegetables- Garden peas and cowpea.

Unit IV

Leguminous vegetables: French bean, Indian bean, cluster bean and broad bean.

Unit V

Leafy vegetables- Lettuce and fenugreek.

VII. Practical

- Floral mechanisms favouring self and often cross pollination;
- Progeny testing and development of inbred lines;
- Selection of desirable plants from breeding population, observations and analysis of various qualitative and quantitative traits in germplasm, hybrids and segregating generations;
- Palynological studies, selfing and crossing techniques;
- Hybrid seed production of vegetable crops in bulk;
- Screening techniques for biotic and abiotic stress resistance in above mentioned crops;
- Molecular marker techniques to identify useful traits in the vegetable crops and special breeding techniques;
- Visit to breeding farms;

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire knowledge about the breeding of self pollinated vegetable crops
- Improve yield, quality, abiotic and biotic resistance and other important traits of vegetable crops
- Understand how to start the breeding of self pollinated vegetable crops

X. Suggested Reading

Allard RW. 1999. *Principles of plant breeding*. John Wiley and Sons.

Basset MJ. (Ed.). 1986. *Breeding vegetable crops*. AVI Publ.
Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005, Plant genetic resources: horticultural crops. Narosa Publ. House.
Fageria MS, Arya PS and Choudhary AK. 2000, *Vegetable crops: Breeding and seed production*. Vol. I. Kalyani.
Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.
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Rai N and Rai M. 2006. *Heterosis breeding in vegetable crops*. New India Publ. Agency.
Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi.
Simmonds NW. 1978. *Principles of crop improvement*. Longman. Singh BD. 1983. Plant Breeding. Kalyani Publishers, New Delhi.
Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. International Book Distributing Co.
Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

I. Course Title : Breeding of Cross Pollinated Vegetable Crops
II. Course Code : VSC 506
III. Credit Hours : (2+1)

IV. Why this course ?

The important methods of breeding in cross-pollinated vegetable species are (i) mass selection, (ii) development of hybrid varieties and (ii) development of synthetic varieties. Since cross-pollinated vegetable crops are naturally hybrid (heterozygous) for many traits and lose vigour as they become purebred (homozygous), a goal of each of these breeding methods is to preserve or restore heterozygosity in cross pollinated vegetable crops. The students of vegetable science who take breeding as a minor subject need to have an understanding of breeding of cross pollinated vegetable crops.

V. Aim of the course

To impart comprehensive knowledge about principles and practices of cross pollinated vegetable crops breeding.

The course is constructed given as under:

No.	Block	Unit
1.	Breeding of cross pollinated vegetable crops	I. Cucurbitaceous crops II. Cole crops III. Root and bulb crops IV. Tuber crops V. Leafy vegetables

VI. Theory

Origin, botany, taxonomy, cytogenetics, genetics, types of pollination and fertilization, mechanism, sterility and incompatibility, breeding objectives, breeding methods (introduction, selection, hybridization, mutation, polyploidy), varieties and varietal characterization, resistance breeding for biotic and abiotic stresses, quality improvement, molecular markers and marker assisted breeding, and QTLs, PPV and FR act

Unit I

Cucurbitaceous crops—Gourds, melons, cucumber, pumpkin and squashes.

Unit II

Cole crops—Cauliflower, cabbage, kohlrabi, broccoli and brussels sprouts.

Unit III

Root and bulb crops—Carrot, radish, turnip, beet root and onion.

Unit IV

Tuber crops—Sweet potato, tapioca, taro and yam.

Unit V

Leafy vegetables—Beet leaf, spinach, amaranth and coriander.

VII. Practical

- Floral mechanisms favouring cross pollination;
- Development of inbred lines;
- Selection of desirable plants from breeding population;
- Observations and analysis of various quantitative and qualitative traits in germplasm, hybrids and segregating generations;
- Induction of flowering, palynological studies, selfing and crossing techniques;
- Hybrid seed production of vegetable crops in bulk; Screening techniques for biotic and abiotic stress resistance in above mentioned crops;
- Demonstration of sib-mating and mixed population;
- Molecular marker techniques to identify useful traits in vegetable crops and special breeding techniques;
- Visit to breeding blocks.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation individual or in group
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire knowledge about the breeding of cross pollinated vegetable crops
- Improve yield, quality, abiotic and biotic resistance, and important traits of cross pollinated vegetable crops
- Understand how to start the breeding of cross pollinated vegetable crops

X. Suggested Reading

Allard RW. 1999. *Principles of plant breeding*. John Wiley and Sons.

Basset MJ. (Ed.). 1986. *Breeding vegetable crops*. AVI Publ.

Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa publ. house.

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Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi.

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Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. International book distributing Co.

Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

I. Course Title : Protected Cultivation of Vegetable CropS

II. Course Code : VSC 507

III. Credit Hours : (2+1)

IV. Why this course ?

India is the second largest producer of vegetable crops in the world. However, its vegetable production is much less than the requirement, if a balanced diet is provided to every individual. There are different ways and means to achieve this target. Protected cultivation, which is the modification of the natural environment to achieve optimum plant growth. Is the most intensive form of crop production with a yield per unit area up to ten times superior to that of a field crop. During winter under north-east Indian conditions, it is difficult to grow tomato, capsicum, cucurbits, french bean, amaranth, etc. in open field. However, various types of protected structure have been developed for growing some high value crops by providing protection from the excessive cold. Production of off-season vegetable nurseries under protected structure has become a profitable business. The main purpose of raising nursery plants in protected structure is to get higher profit and disease free seedlings in off-season to raise early crop in protected and open field condition. The low cost polyhouse is economical for small and marginal farmers, who cannot afford huge cost of high-tech polyhouse. Besides supplying the local markets, the production of polyhouse vegetables is greatly valued for its export potential and plays an important role in the foreign trade balance of several national economies. The students of vegetable science need to have an understanding of protected cultivation of vegetable crops.

V. Aim of the course

To impart latest knowledge about growing of vegetable crops under protected environmental conditions

The course is constructed given as under:

No.	Block	Unit
1.	Protected cultivation of vegetable crops	I. Scope and importance II. Types of protected structure III. Abiotic factors IV. Nursery raising V. Cultivation of crops VI. Solutions to problems

VI. Theory

Unit I

Scope and importance- Concept, scope and importance of protected cultivation of vegetable crops; Principles, design, orientation of structure, low and high cost polyhouses/ greenhouse structures.

Unit II

Types of protected structure- Classification and types of protected structures- greenhouse/ polyhouses, plastic-non plastic low tunnels, plastic walk in tunnels, high roof tunnels with ventilation, insect proof net houses, shed net houses, rain shelters, NVP, climate control greenhouses, hydroponics and aeroponics; Soil and soilless media for bed preparation; Design and installation of drip irrigation and fertigation system.

Unit III

Abiotic factors- Effect of environmental factors and manipulation of temperature, light, carbon dioxide, humidity, etc. on growth and yield of different vegetables.

Unit IV

Nursery raising- High tech vegetable nursery raising in protected structures using plugs and portrays, different media for growing nursery under protected cultivation; Nursery problems and management technologies including fertigation.

Unit V

Cultivation of crops- Regulation of flowering and fruiting in vegetable crops; Technology for raising tomato, sweet pepper, cucumber and other vegetables in protected structures, including varieties and hybrids, training, pruning and staking in growing vegetables under protected structures.

Unit VI

Solutions to problems- Problems of growing vegetables in protected structures and their remedies, physiological disorders, insect and disease management in protected structures; Use of protected structures for seed production; Economics of greenhouse crop production.

VII. Practical

- Study of various types of protected structure;
- Study of different methods to control temperature, carbon dioxide and light;
- Study of different types of growing media, training and pruning systems in greenhouse crops;
- Study of fertigation and nutrient management under protected structures;
- Study of insect pests and diseases in greenhouse and its control;
- Use of protected structures in hybrid seed production of vegetables;
- Economics of protected cultivation (Any one crop);
- Visit to established green/ polyhouses/ shade net houses in the region.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of protected cultivation of vegetable crops in India
- Acquire knowledge about the effect of abiotic factors on growth, flowering and production of vegetable crops
- Gaining knowledge about the designing of various low cost protected structures
- Adopting the raising of vegetable seedlings in low cost protected structures as entrepreneur

X. Suggested Reading

Chadha KL and Kalloo G. (Eds.). 1993-94. *Advances in horticulture*. Malhotra Pub. House.

Chandra S and Som V. 2000. *Cultivating vegetables in green house*. Indian horticulture 45:17-18.

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Parvatha RP. 2016. *Sustainable crop protection under protected cultivation*. E-Book Springer.

Prasad S and Kumar U. 2005. *Greenhouse management for horticultural crops*. 2nd Ed.Agrobios.

Resh HM. 2012. *Hydroponic food production*. 7thEdn. CRC Press.

Singh B. 2005. *Protected cultivation of vegetable crops*. Kalyani publishers, New Delhi

Singh DK and Peter KV. 2014. *Protected cultivation of horticultural crops* (1st Edition) New India publishing agency, New Delhi.

Singh S, Singh B and Sabir N. 2014. *Advances in protected cultivation*. New India publishing agency, New Delhi.
Tiwari GN. 2003. *Green house technology for controlled environment*. Narosa publ. house.

I. Course Title : Seed Production of Vegetable Crops
II. Course Code : VSC 508
III. Credit Hours : (2+1)

IV. Why this course ?

Enhancing yield and quality of vegetable crops depends upon a number of factors. The inputs like fertilizers, irrigation and plant protection measures and suitable agronomic practices contribute greatly towards improving yield and quality of the vegetable produce. If good quality seed is not used, the full benefits of such inputs and agronomic practices can not be realized. The use of high quality seed thus, plays a pivotal role in the production of vegetable crops. It is, therefore, important to use the seed conforming to the prescribed standards. A good quality seed should have high genetic and physical purity, proper moisture content and good germination. It should also be free from seed borne diseases and weed seeds. The quality of the produce will deteriorate if these factors are overlooked. Out crossing, physical admixtures and mutations are the prime factors responsible for the deterioration of seed quality. A variety could be saved from deterioration if proper checks are made at different stages of seed multiplication. It is also extremely important to maintain high genetic purity of a variety. The students of vegetable science need to have an understanding of seed production technology of vegetable crops and their essential processing before supplying them to the market or further use.

V. Aim of the course

To impart a comprehensive knowledge and skills on quality seed production of vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Seed production of vegetable crops	I. Introduction, history, propagation and reproduction II. Agro-climate and methods of seed production III. Seed multiplication and its quality maintenance IV. Seed harvesting, extraction and its processing V. Improved agro-techniques and field and seed standards

VI. Theory

Unit I

Introduction, history, propagation and reproduction—Introduction, definition of seed and its quality, seed morphology, development and maturation; Apomixis and fertilization; Modes of propagation and reproductive behaviour; Pollination mechanisms and sex forms in vegetables; History of vegetable seed production; Status and share of vegetable seeds in seed industry

Unit II

Agro-climate and methods of seed production—Agro-climate and its influence on quality seed production; Deterioration of crop varieties, genetical and agronomic principles of vegetable seed production; Methods of seed production, hybrid seeds and techniques of large scale hybrid seed production; Seed village concept

Unit III

Seed multiplication and its quality maintenance—Seed multiplication ratios and replacement rates in vegetables; Generation system of seed multiplication; Maintenance and production of nucleus, breeder, foundation, certified/ truthful label seeds; Seed quality and mechanisms of genetic purity testing

Unit IV

Seed harvesting, extraction and its processing—Maturity standards; Seed harvesting, curing and extraction; Seed processing, viz., cleaning, drying and treatment of seeds, seed health and quality enhancement, packaging and marketing; Principles of seed storage; Orthodox and recalcitrant seeds; Seed dormancy

Unit V

Improved agro-techniques and field and seed standards—Improved agro-techniques; Field and seed standards in important solanaceous, leguminous and cucurbitaceous vegetables, cole crops, leafy vegetables, bulbous and root crops and okra; clonal propagation and multiplication in vegetative propagated crops; Seed plot technique and true potato seed production in potato

VII. Practical

- Study of floral biology and pollination mechanisms in vegetables;
- Determination of modes of pollination;
- Field and seed standards;
- Use of pollination control mechanisms in hybrid seed production of important vegetables;
- Maturity standards and seed extraction methods;
- Seed sampling and testing;
- Visit to commercial seed production areas;
- Visit to seed processing plant;
- Visit to seed testing laboratories.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of seed production of vegetable crops in India
- Acquire knowledge about the complete seed production technology, extraction and post-extraction processing of vegetable seeds
- Adoption of seed production of vegetable crops as entrepreneur

X. Suggested Reading

Agarwaal PK and Anuradha V. 2018. *Fundamentals of seed science and technology*. Brilliant publications, New Delhi.

Agrawal PK and Dadlani M. (Eds.). 1992. *Techniques in seed science and technology*. South asian Publ.

Agrawal RL. (Ed.). 1997. *Seed technology*. Oxford and IBH.

Basra AS. 2000. *Hybrid seed production in vegetables*. CRC press, Florida, USA.

Bench ALR and Sanchez RA. 2004. *Handbook of seed physiology*. Food products press, NY/ London.

Bendell PE. (Eds.). 1998. *Seed science and technology: Indian forestry species*. Allied Publ.

Chakraborty SK, Prakash S, Sharma SP and Dadlani M. 2002. *Testing of distinctiveness, uniformity and stability for plant variety protection*. IARI, New Delhi

Copland LO and McDonald MB. 2004. *Seed science and technology*, Kluwer Academic Press.

Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: breeding and seed production*. Vol. I. Kalyani Publishers, New Delhi.

George RAT. 1999. *Vegetable seed production* (2nd Edition). CAB International.

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Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. Agro botanical publ.

More TA, Kale PB and Khule BW. 1996. *Vegetable seed production technology*. Maharashtra state seed corp.

Rajan S and Markose BL. 2007. *Propagation of horticultural crops*. New India publ. agency.

Singh NP, Singh DK, Singh YK and Kumar V. 2006. *Vegetable seed production technology*. International book distributing Co.

Singh SP. 2001. *Seed production of commercial vegetables*. Agrotech publ. academy.

Singhal NC. 2003. *Hybrid seed production*. Kalyani publishers, New Delhi

I. Course Title : Production of Underutilized Vegetable Crops

II. Course Code : VSC 509

III. Credit Hours : (2+1)

IV. Why this course ?

With increasing population and fast depletion of natural resources, it has become essential to explore the possibilities of using newer indigenous plant resources. Underutilized crops are plant species that are used traditionally by the country people for their food, fibre, fodder, oil, or medicinal properties but have yet to be adopted by large scale agriculturalists. In general, underutilized plants constitute those plant species that occur as life support species in extreme environmental conditions and threatened habitats, having genetic tolerance to survive under harsh conditions and possess qualities of nutritional and/ or industrial importance for a variety of purposes. Underutilized crops are those plant species with under-exploited potential for contributing to food security, health (nutritional or medicinal), income generation and environmental services. Once the underutilized food crops are properly utilized, they may help to contribute in food security, nutrition, health, income generation and environmental services. The underutilized crops can be defined as the crops, which being region specific are less available, less utilized or rarely used. These underutilized crop species have also been described as *rare*, *minor*, *orphan*, *promising* and little-used vegetable crops. The students of vegetable science need to have an understanding of production technology of underutilized vegetable crops.

V. Aim of the course

To impart knowledge about production technology of lesser utilized vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Production of underutilized vegetable crops	I. Stem and bulb crops II. Cole and salad crops III. Gourds and melons IV. Leafy vegetables V. Yams and beans

VI. Theory

Importance and scope, botany and taxonomy, climate and soil requirement, commercial varieties/ hybrids, improved cultural practices, physiological disorders, harvesting and yield, plant protection measures and post harvest management of:

Unit I

Stem and bulb crops—Asparagus, leek and chinese chive

Unit II

Cole and salad crops—Red cabbage, chinese cabbage, kale, sweet corn and baby corn

Unit III

Leafy vegetables—Celery, parsley, indian spinach (poi), spinach, chenopods, chekurmanis and indigenous vegetables of regional importance

Unit IV

Gourds and melons—Sweet gourd, spine gourd, teasle gourd, round gourd, and little/ Ivy gourd, snake gourd, pointed gourd, kachri, long melon, snap melon and gherkin

Unit V

Yam and beans—Elephant foot yam, yam, yam bean, lima bean and winged bean

VII. Practical

- Identification and botanical description of plants and varieties;
- Seed/ planting material;
- Production, lay out and method of planting;
- Important cultural operations;
- Identification of important pests and diseases and their control;
- Maturity standards and harvesting;
- Visit to local farms.

Teaching Methods/ Activities

- Delivering of lectures by power point presentation
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of production of underutilized vegetable crops in India
- Acquire knowledge about the production technology of underutilized vegetable crops
- Adopting production of lesser utilised crops as entrepreneur

Suggested Reading

Bhat KL. 2001. *Minor vegetables-untapped potential*. Kalyani publishers, New Delhi.

Indira P and Peter KV. 1984. *Unexploited tropical vegetables*. Kerala agricultural university, Kerala.

Pandey AK. 2011. *Aquatic vegetables*. Agrotech publisher academy, New Delhi.

Peter KV. (Eds.). 2007-08. *Underutilized and underexploited horticultural crops*. Vol.1-4, New India publishing agency, Lucknow.

Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 678p.

Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume II and III. Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509 p.

Rana MK. 2018. *Vegetable crop science*. CRC Press Taylor and Francis Group 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL 33487-2742 ISBN: 978-1-1380-3521-8

Rubatzky VE and Yamaguchi M. 1997. *World vegetables: vegetable crops*. NBPGR, New Delhi.

I. Course Title : Systematics of Vegetable Crops

II. Course Code : VSC 510

III. Credit Hours : (1+1)

IV. Why this course ?

Systematics is fundamental to our understanding of the world around us as it provides basis for understanding the patterns of diversity on earth. Vegetable systematics is the science of botanical diversity of vegetable crops on earth, including variation from the level of genes within an individual to individuals, populations and species. The primary aim of systematics is to discover all the branches of the tree of life, document evolutionary changes occurring along those branches, and describe all the species on earth (the tips of the branches). The secondary aim of systematic is to analyze and synthesize information into a classification that reflects evolutionary relationships, to organize this information into a useful, retrievable form to gain insight into evolutionary processes that lead to diversity.

V. Aim of the course

To impart knowledge on morphological, cytological and molecular taxonomy of vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Systematics of vegetable crops	I. Significance of systematics II. Origin and evolution III. Botanical and morphological description IV. Cytology V. Molecular markers

VI. Theory

Unit I

Significance of systematic—Significance of systematics and crop diversity in vegetable crops; Principles of classification; different methods of classification; Salient features of international code of nomenclature of vegetable crops

Unit II

Origin and evolution—Origin, history, evolution and distribution of vegetable crops

Unit III

Botanical and morphological description—Botanical description of families, genera and species covering various tropical, subtropical and temperate vegetables; Morphological keys to identify important families, floral biology, floral formula and diagram; Morphological description of all parts of vegetables

Unit IV

Cytology—Cytological level of various vegetable crops with descriptive keys

Unit V

Molecular markers—Importance of molecular markers in evolution of vegetable crops; Molecular markers as an aid in characterization and taxonomy of vegetable crops

VII. Practical

- Identification, description, classification and maintenance of vegetable species and varieties;
- Survey, collection of allied species and genera locally available;
- Preparation of keys to the species and varieties;
- Methods of preparation of herbarium and specimens.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire knowledge on identification, description, classification and maintenance of vegetable species and varieties
- Collecting locally available allied species of vegetable crops
- Preparing herbarium and specimens

X. Suggested Reading

Chopra GL. 1968. *Angiosperms- systematics and life cycle*. S. Nagin

Dutta AC. 1986. *A class book of botany*. Oxford Univ. Press.

Pandey BP. 1999. *Taxonomy of angiosperm*. S. Chand and Co

Peter KV and Pradeepkumar T. 2008. *Genetics and breeding of vegetables*. (Revised), ICAR.

Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 678p.

Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume II.Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509p.

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Simmonds NW and Smartt J. 1995. *Evolution of crop plants*. Wiley-Blackwell.
Soule J. 1985. *Glossary for Horticultural Crops*. John Wiley and Sons.
Srivastava U, Mahajan RK, Gangopadyay KK, Singh M and Dhillon BS. 2001. *Minimal descriptors of agri-horticultural crops*. Part-II: Vegetable Crops. NBPGR, New Delhi.
Vasistha. 1998. *Taxonomy of angiosperm*. Kalyani Publishers, New Delhi.
Vincent ER and Yamaguchi M. 1997. *World vegetables*. 2nd Ed. Chapman and Hall.

I. Course Title : Organic Vegetable Production

II. Course Code : VSC 511

III. Credit Hours : (1+1)

IV. Why this course ?

Organic vegetable farming is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. Organic farming has been simply defined as a production system working in partnership with nature to produce vegetable crops. The current trend towards increasing popularity of organically produced vegetables is relatively new. The objective of organic farming is to produce safer food and to keep the environment healthy. During the decade of nineties, the interest in organic farming began to creep into the mainstream consumer purchases. Currently, it appears to be an influx of business oriented producers into the organic production field. The increasing popularity of organic food among the elite societies is due to the belief that food produced with this system is free of pesticides and has greater nutritive value than conventionally produced food. The students of vegetable science need to have an understanding of organic vegetable farming technology.

V. Aim of the course

To elucidate principles, concepts and their applications in organic farming of vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Organic vegetable production	1. Importance and principles 2. Organic production of vegetables 3. Managing soil fertility 4. Composting methods 5. Certification and export

VI. Theory

Unit I

Importance and principles—Importance, principles, perspective, concepts and components of organic farming in vegetable crops

Unit II

Organic production of vegetables—Organic production of vegetable crops, viz., Solanaceous, Cucurbitaceous, Cole, root and tuber crops

Unit III

Managing soil fertility—Managing soil fertility, mulching, raising green manure crops, weed management in organic farming system; Crop rotation in organic production; Processing and quality control of organic vegetable produce

Unit IV

Composting methods—Indigenous methods of composting, Panchyagavvya, Biodynamics preparations and their application; ITKs in organic vegetable farming; Role of botanicals and bio-control agents in the management of pests and diseases in vegetable crops

Unit V

Certification and export—Techniques of natural vegetable farming, GAP and GMP-certification of organic products; Export- opportunity and challenges

VII. Practical

- Methods of preparation and use of compost, vermicompost, biofertilizers and biopesticides;
- Soil solarisation;
- Use of green manures;
- Waste management; Organic soil amendments in organic production of vegetable crops;
- Weed, pest and disease management in organic vegetable production;
- Visit to organic fields and marketing centres.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of organic vegetable production in India
- Acquire knowledge about the organic vegetable production technology
- Adopting production of organic vegetable crops a s entrepreneur

X. Suggested Reading

Dahama AK. 2005. *Organic farming for sustainable agriculture*. 2nd Ed. Agrobios.
Gehlot G. 2005. *Organic farming; standards, accreditation certification and inspection*. Agrobios.
Palaniappan SP and Annadorai K. 2003. *Organic farming, theory and practice*. Scientific publ.
Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2008. *Management of horticultural crops*. New India Publ. Agency.
Shivashankar K. 1997. *Food security in harmony with nature. 3rd IFOAMASIA,* Scientific Conf. 1- 4 December, UAS, Bangalore.

I. Course Title : Production of Spice Crops

II. Course Code : VSC 512

III. Credit Hours : (2+1)

IV. Why this course ?

Spices are an important part of human history and played an important role in the development of most cultures around the world. Spice may be a seed, fruit, root, bark, or any other plant substance primarily used for flavouring, colouring, or preserving food. Spices are distinguished from herbs, which are the leaves, flowers, or stems of plants used for flavouring or as a garnish. Many spices have antimicrobial properties, because of which why spices are more commonly used in warmer climates, which have more infectious diseases, and use of spices is prominent in meat, which is predominantly susceptible to spoiling. The students of vegetable science need to have an understanding of production technology of spices and their processing before supplying them to the market or further use.

V. Aim of the course

To impart basic knowledge about the importance and production technology of spices grown in India

The course is constructed given as under:

No.	Block	Unit
1.	Production of spice crops	1. Fruit spices 2. Bud and kernel spices 3. Underground spice crops 4. Seed spices 5. Tree spices

VI. Theory

Introduction and importance of spice crops- historical accent, present status (national and international), future prospects, botany and taxonomy, climatic and soil requirement, commercial cultivars/ hybrids, site selection, layout, sowing/ planting time and methods, seed rate and seed treatment, nutritional and irrigation requirement, intercropping, mixed cropping, intercultural operations, weed control, mulching, physiological disorders, harvesting, post-harvest management, plant protection measures, quality control and pharmaceutical significance of crops mentioned below:

Unit I

Fruit spices- Black pepper, small cardamom, large cardamom and allspice

Unit II

Bud and kernel- Clove and nutmeg

Unit III

Underground spices- Turmeric, ginger and garlic

Unit IV

Seed spices- Coriander, fenugreek, cumin, fennel, ajowain, dill and celery

Unit V

Tree spices- Cinnamon, tamarind, garcinia and vanilla

VII. Practical

- Identification of seeds and plants;
- Botanical description of plant;
- Preparation of spice herbarium;
- Propagation;
- Nursery raising;

- Field layout and method of planting;
- Cultural practices;
- Harvesting, drying, storage, packaging and processing;
- Value addition;
- Short term experiments on spice crops.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:
- Appreciate the scope and scenario of production of spice crops in India
- Acquire knowledge about the production technology and processing of spice crops
- Adopting production of spice crops as entrepreneur

X. Suggested Reading

Agarwal S, Sastry EVD and Sharma RK. 2001. *Seed spices: production, quality, export*. Pointer Publication.
Arya PS. 2003. *Spice crops of India*. Kalyani.
Bhattacharjee SK. 2000. *Hand book of aromatic plants*. Pointer publications.
Bose TK, Mitra SK, Farooqi SK and Sadhu MK. (Eds.). 1999. *Tropical horticulture*.Vol.I. Naya Prokash.
Chadha KL and Rethinam P. (Eds.). 1993. *Advances in horticulture*. Vols. IX-X. *Plantation crops and spices*. Malhotra Publ. House.
Gupta S. (Ed.). *Hand book of spices and packaging with formulae*. engineers India research institute, New Delhi.
Kumar NA, Khader P, Rangaswami and Irulappan I. 2000. *Introduction to spices, plantation crops, medicinal and aromatic plants*. Oxford and IBH.
Nybe EV, Miniraj N and Peter KV. 2007. *Spices*. New India Publ. Agency.
Parthasarthy VA, Kandiannan V and Srinivasan V. 2008. *Organic spices*. New India Publ. Agency.
Peter KV. 2001. *Hand book of herbs and spices*. Vols. I-III. Woodhead Publ. Co. UK and CRC USA.
Pruthi JS. (Ed.). 1998. *Spices and condiments*. National Book Trust
Pruthi JS. 2001. *Minor spices and condiments- crop management and post harvest technology*. ICAR.
Purseglove JW, Brown EG, Green CL and Robbins SRJ. (Eds.). 1981. *Spices*. Vols. I, II. Longman.
Shanmugavelu KG, Kumar N and Peter KV. 2002. *Production technology of spices and plantation crops*. Agrobios.
Thamburaj S and Singh N. (Eds.). 2004. *Vegetables, tuber crops and spices*. ICAR.
Tiwari RS and Agarwal A. 2004. *Production technology of spices*. International Book Distr. Co.
Varmudy V. 2001. *Marketing of spices*. Daya Publ. House.

I. Course Title : Processing of Vegetable Crops
II. Course Code : VSC 513
III. Credit Hours : (1+1)

IV. Why this course ?

In India, agriculture is the basis of economy. Agricultural industries and related activities, which can be termed as agriculturally based vegetable processing, can account for a considerable proportion of their output. Both established and planned vegetable processing projects aim at solving a very clearly identified developmental problems. The growers sustain substantial losses due to insufficient demand in the market, weak infrastructure, poor transportation and perishable nature of the vegetable crops. During the postharvest glut, the loss is considerable and often some of the produce are fed to the animals or allowed to decay. Even the established vegetable canning industries or small/ medium scale processing centres suffer huge loss due to erratic supplies since the growers like to sell their produce in the open market directly to the consumers, or the produce may not be of enough high quality to process but it might be good enough for the table use, meaning that processing is seriously underexploited. The main objective of vegetable processing is to supply wholesome, safe, nutritious and acceptable food to the consumers throughout the year. Vegetable processing also aims to replace imported products like squash, jams, tomato sauces, pickles, etc., besides earning foreign exchange by exporting finished or semi-processed products. The students of vegetable science need to have an understanding of vegetable processing.

V. Aim of the course

To educate the students about the principles and practices of processing in vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Processing of vegetable crops	I Present status II Spoilage and biochemical changes III Processing equipments IV Quality control V Value addition

VI. Theory

Unit I

Present status—Present status and future prospects of vegetable preservation industry in India

Unit II

Spoilage and biochemical changes—Spoilage of fresh and processed vegetable produce; biochemical changes and enzymes associated with spoilage of vegetable produce; Principal spoilage organisms, food poisoning and their control measures; Role of microorganisms in food preservation

Unit III

Processing equipments—Raw material for processing; Primary and minimal processing; Processing equipments; Layout and establishment of processing industry; FPO licence; Importance of hygiene; Plant sanitation

Unit IV

Quality control—Quality assurance and quality control, TQM, GMP; Food standards-FPO, PFA, etc.; Food laws and regulations; Food safety- hazard analysis and critical control points (HACCP); Labeling and labeling act and nutrition labeling

Unit V

Value addition—Major value added vegetable products; Utilization of byproducts of vegetable processing industry; Management of processing industry waste; Investment analysis; Principles and methods of sensory evaluation of fresh and processed vegetables

VII. Practical

- Study of machinery and equipments used in processing of vegetable produce;
- Chemical analysis for nutritive value of fresh and processed vegetable;
- Study of different types of spoilage in fresh as well as processed vegetable produce;
- Classification and identification of spoilage organisms;
- Study of biochemical changes and enzymes associated with spoilage;
- Laboratory examination of vegetable products;
- Sensory evaluation of fresh and processed vegetables;
- Study of food standards- National, international, CODEX Alimentarius;
- Visit to processing units to study the layout, hygiene, sanitation and waste management.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Appreciate the scope and scenario of vegetable processing in India
- Acquire knowledge about the processing technology of vegetable crops
- Adopting processing products of vegetable crops at small or medium scale
- Adopt processing of vegetable crops as entrepreneur

X. Suggested Reading

Arthey D and Dennis C. 1996. *Vegetable processing*. Blackie/ Springer-Verlag.
Chadha DS. 2006. *The Prevention of food adulteration act*. Confed. of Indian Industry.
Desrosier NW. 1977. *Elements and technology*. AVI Publ. Co.
FAO. 1997. *Fruit and Vegetable processing*. FAO.
FAO. *CODEX Alimentarius: Joint FAO/ WHO food standards programme*. 2nd Ed. Vol. VB. *tropical fresh fruits and vegetables*. FAO.
FAO. *Food quality and safety systems- training manual on food hygiene and haccp*. FAO.
Fellow's P. 1988. Food processing technology. Ellis Horwood International.
Frazier WC and Westhoff DC. 1995. *Food microbiology*. 4th Ed. Tata McGraw Hill.
Giridharilal GS Siddappa and Tandon GL. 1986, *Preservation of fruits and vegetables*. ICAR.
Gisela J. 1985. *Sensory evaluation of food- theory and practices*. Ellis Horwood.
Graham HD. 1980. *Safety of foods*. AVI Publ. Co.
Hildegrade H and Lawless HT. 1997. *Sensory evaluation of food*. CBS.
Joslyn M and Heid *Food processing operations*.AVI Publ. Co.
Mahindru SN. 2004. *Food safety: concepts and reality*. APH Publ. Corp.
Ranganna S. 1986. *Handbook of analysis and quality control for fruit and vegetable products*. 2nd Ed. Tata-McGraw Hill.
Shapiro R. 1995. *Nutrition labeling handbook*. Marcel Dekker.
Srivastava RP and Kumar S. 2003. *Fruit and vegetable preservation: principles and practices*. 3rd Ed. International Book Distri. Co.

Tressler and Joslyn MA. 1971. *Fruit and vegetable juice processing technology*. AVI Publ. Co.
Verma LR and Joshi VK. 2000. *Postharvest technology of fruits and vegetables: handling, processing, fermentation and waste management*. Indus Publ. Co.

I. Course Title : Postharvest Management of Vegetable Crops
II. Course Code : VSC 514
III. Credit Hours : (2+1)

IV. Why this course ?

Vegetables are highly perishable crops as they have great quantity and quality loss after harvest. Hence, they require integrated approach to arrest their spoilage, which causes tonnes of vegetable produce annually. Lack of postharvest awareness and inadequacy of equipments are the major problems in postharvest chain, which lead to a serious post-harvest loss in the developing countries every year. A comprehensive understanding of postharvest factors causing deterioration is necessary to overcome these challenges. Pre and postharvest management such as use of improved varieties, good cultural practices, good pre and postharvest handling practices, management of temperature, relative humidity and storage atmosphere according to crop requirement, use of permitted chemicals, design of appropriate packaging material and storage structures are some of the control measures used in reducing postharvest losses, therefore, this course was customized.

V. Aim of the course

To facilitate deeper understanding of principles and to acquaint the student with proper handling and management technologies of vegetable crops for minimizing the post-harvest losses

The course is organized as follows:

No.	Blocks	Units
1.	Post-harvest management of vegetable crops	I Importance and scope II Maturity indices and biochemistry III Harvesting and losses factors IV Packinghouse operations V Methods of storage

VI. Theory

Unit I

Importance and scope—Importance and scope of post-harvest management of vegetables

Unit II

Maturity indices and biochemistry—Maturity indices and standards for different vegetables; Methods of maturity determination; Biochemistry of maturity and ripening; Enzymatic and textural changes; Ethylene evolution and ethylene management; Respiration and transpiration along with their regulation methods

Unit III

Harvesting and losses factors—Harvesting tools and practices for specific market requirement; Postharvest physical and biochemical changes; Preharvest practices and other factors affecting postharvest losses

Unit IV

Packing house operations—Packing house operations; Commodity pretreatments chemicals, wax coating, precooling and irradiation; Packaging of vegetables, prevention from infestation, management of postharvest diseases and principles of transportation

Unit V

Methods of storage—Ventilated, refrigerated, modified atmosphere and controlled atmosphere storage, hypobaric storage and cold storage; Zero-energy cool chamber, storage disorders like chilling injury in vegetables

VII. Practical

- Studies on stages and maturing indices;
- Ripening of commercially important vegetable crops;
- Studies of harvesting, pre-cooling, pre-treatments, physiological disorders- chilling injury;
- Improved packaging;
- Use of chemicals for ripening and enhancing shelf life of vegetables;
- Physiological loss in weight, estimation of transpiration, respiration rate and ethylene release;
- Storage of important vegetables;
- Cold chain management;
- Visit to commercial packinghouse, cold storage and control atmosphere storage.

VIII. Teaching Methods/ Activities

- Classroom lectures including ppt.
- Students group discussion
- Individual or group assignments (writing and speaking)
- Presentation of practical handwork

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Regulation of postharvest losses by using chemicals and growth regulators
- Pre and postharvest treatments for extending shelf life of vegetable crops
- Packinghouse operations for extending the shelf life of vegetable crops
- Successful storage of vegetable crops

X. Suggested Reading

Chadha KL and Pareek OP. 1996. *Advances in horticulture*. Vol. IV. Malhotra Publ. House.

Chattopadhyay SK. 2007. *Handling, transportation and storage of fruit and vegetables*. Gene-Tech books, New Delhi.

Haid NF and Salunkhe SK. 1997. *Postharvest physiology and handling of fruits and vegetables*. Grenada Publ.

Mitra SK. 1997. *Postharvest physiology and storage of tropical and sub-tropical fruits*. CABI.

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Ranganna S. 1997. *Handbook of analysis and quality control for fruit and vegetable products*. Tata McGraw-Hill.

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Verma LR and Joshi VK. 2000. *Postharvest technology of fruits and vegetables: handling, processing, fermentation and waste management*. Indus Publishing Company, New Delhi, India. ISBN 8173871086.

Willis R, McGlassen WB, Graham D and Joyce D. 1998. *Postharvest: An introduction to the physiology and handling of fruits, vegetables and ornamentals*. CABI.

Wills RBH and Golding J. 2016. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*, CABI Publishing, ISBN 9781786391483.

Wills RBH and Golding J. 2017. *Advances in postharvest fruit and vegetable technology*, CRC Press, ISBN 9781138894051.

Course Title with Credit Load
Ph.D. (Hort.) in Vegetable Science

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
VSC 601*	Recent Trends in Vegetable Production	3+0
VSC 602*	Advances in Breeding of Vegetable Crops	3+0
VSC 603	Abiotic Stress Management in Vegetable Crops	2+1
VSC 604	Seed Certification, Processing and Storage of Vegetable Crops	2+1
VSC 605	Breeding for Special Traits in Vegetable Crops	2+0
VSC 606	Biodiversity and Conservation of Vegetable Crops	2+1
VSC 607	Biotechnological Approaches in Vegetable Crops	2+1
VSC 608	Advanced Laboratory Techniques for Vegetable Crops	1+2
	Minor courses	06
	Supporting courses	05
VSC 691	Seminar I	0+1
VSC 692	Seminar II	0+1
VSC 699	Research	0+75
	Total Credits	100

*Compulsory among major courses

Course Contents
Ph.D. (Hort.) in Vegetable Science

I. Course Title : Recent Trends in Vegetable Production
II. Course Code : VSC 601
III. Credit Hours : (3+0)

IV. Why this course ?

India is the second largest producer of vegetables in the world, next only to China. Most challenging task is to ensure for continuous and enough supply of vegetables to growing population. Urban areas are experiencing substantial increase in population; this growth is accompanied with change in food habits and rising concerns for food quality. Here, food quality refers to the optimum levels of the nutrition in the food along with the minimized amount of the chemical (pesticides/ fertilizers) residues used in the production of the vegetables. Vegetables are being highly seasonal, perishable are also capital and labour intensive and need care in handling and transportation. Environmental stress (climate change) and shortage of water and land resources are major constraints haunting the production. Though the advances in science and information technology has resulted in more comfortable world with global linkages, these advances has led to changes in production practices. Thus, the students of vegetable science need to have an understanding of recent trends in production technology of vegetable crops and their management.

V. Aim of the course

To keep abreast with latest developments and trends in production technology of vegetable crops.

The course is constructed given as under:

No.	Block	Unit
1	Recent trends in vegetable production	1. Solanaceous crops 2. Cole crops 3. Okra, onion, peas and beans, amaranth and drumstick. 4. Root crops and cucurbits 5. Tuber crops

VI. Theory

Present status and prospects of vegetable cultivation; nutritional, antioxidant and medicinal values; climate and soil as critical factors in vegetable production; choice of varieties; Hi-tech nursery management; modern concepts in water and weed management; physiological basis of growth, yield and quality as influenced by chemicals and growth regulators; role of organic manures, inorganic fertilizers, micronutrients and biofertilizers; response of genotypes to low and high nutrient management, nutritional deficiencies/ disorders and correction methods; different cropping systems; mulching; Protected cultivation of vegetables, containerized culture for year round vegetable production; low cost polyhouse; nethouse production; crop modelling, organic gardening; vegetable production for pigments, export and processing of:

Unit I

Solanaceous crops: Tomato, brinjal, chilli, sweet pepper and potato.

Unit II

Cole crops: Cabbage, cauliflower and knol-khol, sprouting broccoli.

Unit III

Okra, onion, peas and beans, amaranth and drumstick.

Unit IV

Root crops and cucurbits: Carrot, beet root, turnip and radish and cucurbits

Unit V

Tuber crops: Sweet potato, Cassava, elephant foot yam, Dioscorea and taro.

VII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Group discussion

VIII. Learning outcome

After successful completion of this course, the students are exposed to:

- Acquire the knowledge about recent trends in production technology of vegetable crops

IX. Suggested Reading

Bose TK and Som NG. 1986. *Vegetable crops of India*. Naya prokash.

Bose TK, Kabir J, Maity TK, Parthasarathy VA and Som MG. 2003. *Vegetable crops*. Vols. I-III. Naya Udyog.

Brewster JL. 1994. *Onions and other vegetable alliums*. CABI.

Chadha KL and Kalloo G (Eds.). 1993-94. *Advances in horticulture* Vols. V-X. Malhotra Publ. House.

Chadha KL (Ed.). 2002. *Hand book of horticulture*. ICAR.

Chauhan DVS (Ed.). 1986. *Vegetable production in India*. Ram prasad and Sons.

Fageria MS, Choudhary BR and Dhaka RS. 2000. *Vegetable crops: production technology*. Vol. II. Kalyani.

FFTC. *Improved vegetable production in Asia*. Book Series No. 36.

Ghosh SP, Ramanujam T, Jos JS, Moorthy SN and Nair RG. 1988. *Tuber crops*. Oxford and IBH.

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Hazra P. 2016. *Vegetable science*. 2ndedn, Kalyani publishers, Ludhiana.

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Kallo G and Singh K. (Ed.). 2001. *Emerging scenario in vegetable research and development*. Research periodicals and Book Publ. House.

Kurup GT, Palanisami MS, Potty VP, Padmaja G, Kabeerathuma S and Pallai SV. 1996. *Tropical tuber crops, problems, prospects and future strategies*. Oxford and IBH.

Rana MK. 2008. *Olericulture in India*. Kalyani Publishers, New Delhi.

Rana MK. 2008. *Scientific cultivation of vegetables*. Kalyani Publishers, New Delhi.

Rubatzky VE and Yamaguchi M. (Eds.). 1997. *World vegetables: principles, production and nutritive values*. Chapman and Hall.
Saini GS. 2001. *A Text Book of oleri and flori culture*. Aman Publishing House.
Salunkhe DK and Kadam SS. (Ed.). 1998. *Hand book of vegetable science and technology: production, composition, storage and processing*. Marcel Dekker.
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Sin MT and Onwueme IC. 1978. *The tropical tuber crops*. John Wiley and Sons.
Singh DK. 2007. *Modern vegetable varieties and production technology*. International book distributing Co.
Singh NP, Bhardwaj AK, Kumar A and Singh KM. 2004. *Modern technology on Vegetable production*. International book distr. Co.
Singh PK, Dasgupta SK and Tripathi SK. 2006. *Hybrid vegetable development*. International book distr. Co.
Singh SP. (Ed.). 1989. *Production technology of vegetable crops*. Agril. Comm. Res. Centre.
Thamburaj S and Singh N. (Eds.). 2004. *Vegetables, tuber crops and spices*. ICAR.
Thompson HC and Kelly WC. (Eds.). 1978. *Vegetable crops*. Tata McGraw-Hill.

I. Course Title : Advances in Breeding of Vegetable Crops
II. Course Code : VSC 602
III. Credit Hours : (3 +0)

IV. Why this course ?

The improvement of vegetable crops has until recently, been largely confined to conventional breeding approaches and such programmes rely on hybridization of plants which have desirable heritable characteristics and on naturally or artificially induced random mutations. The introduction of new genetic information can result in increased resistance to insect pest, diseases tolerance to environmental condition, improved quality, etc. The modern biotechnological tools like molecular assisted selection, double haploidy, genetic engineering, etc. can be of immense importance for rapid development of superior varieties with desirable qualitative and quantitative traits. Therefore, conventional breeding in conjunction with molecular biology has bright prospects of developing high yielding vegetable varieties with high nutraceuticals and bio active compounds suitable for fresh as well as processed market. The students of vegetable science who are having breeding as major subject need to have an understanding of recent technologies in vegetable crops.

V. Aim of the course

To impart knowledge on the recent research trends and advances in breeding of vegetable crops.

The course is constructed given as under:

No.	Block	Unit
1	Advances in Breeding of vegetable crops	I. Solanaceous crops and okra II. Cucurbits and Cole crops III. Legumes and leafy vegetables IV. Root crops and onion V. Tuber crops

VI. Theory

Evolution, distribution, cytogenetics, Genetics and genetic resources, wild relatives, genetic divergence, hybridization, inheritance of qualitative and quantitative traits, heterosis breeding, plant idotype concept and selection indices, breeding mechanisms, pre breeding, mutation breeding, ploidy breeding, breeding for biotic and abiotic stresses, breeding techniques for improving quality and processing characters, bio-fortification, *in-vitro* breeding, marker assisted breeding, haploidy, development of transgenic.

Unit I

Solanaceous crops—Tomato, Brinjal, Hot Peeper, Sweet Pepper, Okra and Potato

Unit II

Cucurbits and Cole crops

Unit III

Legumes and leafy vegetables—Peas and Beans, Amaranth, Palak, Chenopods and Lettuce.

Unit IV

Root crops and onion—Carrot, Beetroot, Radish, Turnip, Onion

Unit V

Tuber crops—Sweet potato, Tapioca, Elephant foot yam, Colocasia, Dioscorea

VII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Group discussion

VIII. Learning outcome

After successful completion of this course, the students are exposed to:

- Breeding objectives and trends
- Recent Adavnces in vegetable breeding

IX. Suggested Reading

Allard RW. 1999. *Principle of plant breeding*. John Willey and Sons, USA.

Basset MJ. (Ed.). 1986. Breeding vegetable crops. AVI Publ.

Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa Publ. House.

Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: Breeding and seed production*. Vol. I. Kalyani.

Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.

Hayes HK, Immer FR and Smith DC. 1955. *Methods of plant breeding*. McGraw-Hill.

Hayward MD, Bosemark NO and Romagosa I. (Eds.). 1993. *Plant Breeding-principles and prospects*. Chapman and Hall.

Hazra P and Som MG. 2015. *Vegetable science* (Second revised edition), Kalyani publishers, Ludhiana, 598 p

Hazra P and Som MG. 2016. *Vegetable seed production and hybrid technology* (Second revised edition), Kalyani Publishers, Ludhiana, 459 p

Kalloo G. 1988. *Vegetable breeding* (Vol. I, II, III). CRC Press, Fl, USA.

Kalloo G. 1998. *Vegetable breeding*. Vols. I-III (Combined Ed.). Panima Edu. Book Agency.

Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. Agro Botanical Publ.

Paroda RS and Kalloo G. (Eds.). 1995. *Vegetable research with special reference to hybrid technology in Asia-Pacific Region*. FAO.

Peter KV and Pradeepkumar T. 2008. *Genetics and breeding of vegetables*. Revised, ICAR.

Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 678p.
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Rai N and Rai M. 2006. *Heterosis breeding in vegetable crops*. New India Publ. Agency.
Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi.
Simmonds NW. 1978. *Principles of crop improvement*. Longman. Singh BD. 1983. Plant Breeding. Kalyani Publishers, New Delhi.
Singh BD. 1983. *Plant breeding*. Kalyani Publishers, New Delhi.
Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. International Book Distributing Co.
Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

I. Course Title : Abiotic Stress Management in Vegetable Crops
II. Course Code : VSC 603
III. Credit Hours : (2+1)

IV. Why this course ?

Improvement of vegetable crops has traditionally focused on enhancing a plant's ability to resist diseases or insects. That is evidenced by the large number of disease- or insect-resistant cultivars or germplasm released and used. Research on crop resistance or tolerance to abiotic stresses (heat, cold, drought, flood, salt, pH, etc.) has not received much attention. However, that is changing as a result of the research and publicity of global warming. The changing environments pose serious and imminent threats to vegetable production and place unprecedented pressures on the sustainability of vegetable production. The challenges and opportunities coexist for our dynamic and resilient industry. In addition to conserving resources, we should mitigate abiotic stresses and adapt to the warming planet. The student of vegetable science need to know the different methods involved to mitigate the abiotic stress in vegetable crops.

V. Aim of the course

To update knowledge on the recent research trends in the field of abiotic stress management in vegetables.

- To teach management practices to mitigate abiotic stress in vegetable crops

The course is constructed given as under:

No.	Block	Unit
1	Abiotic stress management in vegetable crops	I Environmental stress II Mechanism and measurements of tolerance III Soil-plant-water relations IV Techniques of vegetable growing under high stress condition V Use of chemicals

VI. Theory

Unit I

Environmental stress—its types, soil parameters including pH, classification of vegetable crops based on susceptibility and tolerance to various types of stress.

Unit II

Mechanism and measurements—tolerance to drought, water logging, soil salinity, frost and heat stress in vegetable crops.

Unit III

Soil-plant-water relations—under different stress conditions in vegetable crops production and their management practices.

Unit IV

Techniques of vegetable growing under water deficit, water logging, salinity and sodicity.

Unit V

Use of chemicals—techniques of vegetable growing under high and low temperature conditions, use of chemicals and antitranspirants in alleviation of different stresses.

VII. Practical

- Identification of susceptibility and tolerance symptoms to various types of stress in vegetable crops;
- Measurement of tolerance to various stresses in vegetable crops;
- Short term experiments on growing vegetable under water deficit, water logging, salinity and sodicity, high and low temperature conditions;
- Use of chemicals for alleviation of different stresses.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedure
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire the knowledge about effect of different abiotic stresses on vegetables
- Methods to mitigate abiotic stress in vegetables

X. Suggested Reading

Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa Publ. House.

Dwivedi P and Dwivedi RS. 2005. *Physiology of abiotic stress in plants*. Agrobios.

Janick JJ. 1986. *Horticultural science*. 4th Ed. WH Freeman and Co.

Kaloo G and Singh K. 2001. *Emerging scenario in vegetable research and development*. Research periodicals and book publ. house.

Kaloo G. 1994.*Vegetable breeding*. Vols. I-III. Vedams eBooks.

Lerner HR. (Eds.). 1999. *Plant responses to environmental stresses*. Marcel Decker.

Maloo SR. 2003. *Abiotic stresses and crop productivity*.Agrotech Publ. Academy.

Narendra T. *et al.* 2012. *Improving crops resistance to abiotic stress*. Wiley and Sons.US.

Peter KV and Pradeep Kumar T. 2008. *Genetics and breeding of vegetables*. (Revised Ed.). ICAR.

Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* volume II.Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509p.

Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* volume III. Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 634p.

Ram HH. 2001. *Vegetable breeding*. Kalyani.

Rao NK. (Eds.). 2016. *Abiotic stress physiology of horticultural crops*. Springer publication.

I. Course Title : Seed Certification, Processing and Storage of Vegetable Seeds

II. Course Code : VSC 604

III. Credit Hours : (2+1)

IV. Why this course ?

Every farmer should able to access healthy seeds which are genetically pure, with high seed vigour and good germination percentage. Timely availability of good quality seeds at reasonable price ensures good yield and profit to the farmers. The seeds plays a vital role in agriculture and acts as a carrier of the genetic potential of varieties. Quality seed production which follows efficient certification procedures plays a major role in the increase of food production of our country. To ensure this, the Government has prescribed standards and has brought in seed production techniques, testing, certification and marketing procedures through the Seeds Act, 1966. In the current scenario, the demand for good quality certified seeds far exceed the availability in the market. This manual provides details about production and procurement of good quality seeds.

V. Aim of the course

To impart the knowledge on seed certification, processing and storage of vegetable seeds

VI. Theory

Unit I

Seed certification, history, concepts and objectives, seed certification agency, phases of seed certification, Indian Minimum seed Certification standards, Planning and management of seed certification programmes.

Unit II

Principles and procedures of field inspection, seed sampling, testing and granting certification, OECD certification Schemes.

Unit III

Principles of seed processing, Methods of seed drying and cleaning, seed processing plant- Layout and design, seed treatment, seed quality enhancement, packaging and marketing.

Unit IV

Principles of Seed Storage, orthodox/ recalcitrant seeds, types of storage (open, bulk, controlled, germplasm, cryopreservation), factors affecting seed longevity in storage (Pre and post harvest factors).

Unit V

Seed aging and deterioration, maintenance of seed viability and vigor during storage, storage methods, storage structures, transportation and marketing of seeds.

VII. Practical

- General procedures of seed certification;
- Field inspection and standards;
- Isolation and rouging;
- Inspection and sampling at harvesting, threshing and processing;
- Testing physical purity, germination and moisture, grow-out test;

- Visit to regulatory seed testing and plant quarantine laboratories;
- Seed processing plants and commercial seed stores.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation individual or in group
- Hands on training of different procedure
- Group discussion

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Acquire the knowledge on seed certification
- Acquire the knowledge on seed processing and storage

X. Suggested Reading

Agarwaal PK and Anuradha V. 2018. *Fundamentals of seed science and technology*. Brilliant publications, New Delhi.

Basra AS. 2000. *Hybrid seed production in vegetables*. CRC press, Florida, USA.

Bench ALR and Sanchez RA. 2004. *Handbook of seed physiology*. Food products press, NY/ London.

Chakraborty SK, Prakash S, Sharma SP and Dadlani M. 2002. *Testing of distinctiveness, uniformity and stability for plant variety protection*. IARI, New Delhi

Copland LO and McDonald MB. 2004. *Seed science and technology*, Kluwer academic press.

Fageria MS, Arya PS and Choudhry AK. 2000. *Vegetable crops: breeding and seed production* Vol 1. Kalyani publishers, New Delhi.

George RAT. 1999. *Vegetable seed production* (2nd Edition). CAB International.

Hazra P and Som MG. 2016. *Vegetable seed production and hybrid technology* (Second revised edition), Kalyani publishers, Ludhiana, 459p

Kalloo G, Jain SK, Vari AK and Srivastava U. 2006. *Seed: A global perspective*. Associated publishing company, New Delhi.

Singhal NC. 2003. *Hybrid seed production*. Kalyani publishers, New Delhi.

I. Course Title : Breeding for Special Traits in Vegetable Crops

II. Course Code : VSC 605

III. Credit Hours : (2+0)

IV. Why this course ?

Many epidemiological studies reveal that people having a high level of consumption of vegetables presents a better health and lower risk of chronic diseases, including cardiovascular diseases and different types of cancer. Vegetables contain many bioactive compounds and represent a major source of antioxidants and other compounds that are beneficial to human health. Consumers are increasingly demanding vegetables with bioactive properties that contribute to maintaining a good health and preventing diseases. In consequence, breeding programmes in vegetables are increasingly considering the content in bioactive compounds as a major breeding objective. In this way, there is an increasing number of breeding programmes and scientific studied aimed at improving the content in bioactive compounds of vegetables, and the trend seems that will continuing in the coming years. In this respect, the particular course has been designed for students of Vegetable Science department.

V. Aim of the course

To impart knowledge on recent developments in breeding for improved nutritional quality in important vegetable crops

VI. Theory

Important nutrient constituents in vegetables and their role in human diet. Genetics of nutrients. Genetic and genomic resources for improving quality traits in vegetables, breeding strategies for developing varieties with improved nutrition for market and industrial purposes. Molecular and biotechnological approaches in breeding suitable cultivars of different crops for micronutrients and color content.

Unit I

Brassica group, carrot and beetroot.

Unit II

Tomato, brinjal, peppers and potato.

Unit III

Green leafy vegetables, Legume crops and okra.

Unit IV

Cucurbitaceous vegetable crops and edible Alliums.

Unit V

Biofortification in vegetable crops, genetic engineering for improvement of quality traits in vegetable crops, bioavailability of dietary nutrients from improved vegetable crops and impact on micronutrient malnutrition, achievements and future prospects in breeding for quality traits in vegetables.

VII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedure
- Group discussion

VIII. Learning outcome

After successful completion of this course, the students are expected to:

- Know about various special characters of vegetables
- The recent breeding methods to achieve special characters in vegetables

IX. Suggested Reading

Allard RW. 1999. *Principles of plant breeding*. John Wiley and Sons.

Basset MJ. (Ed.). 1986. *Breeding vegetable crops*. AVI Publ.

Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa Publ. House.

Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: Breeding and seed production*. Vol. I. Kalyani.

Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.

Hayes HK, Immer FR and Smith DC. 1955. *Methods of plant breeding*. McGraw-Hill.

Hayward MD, Bosemark NO and Romagosa I. (Eds.). 1993. *Plant Breeding-principles and prospects*. Chapman and Hall.

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Rai N and Rai M. 2006. *Heterosis breeding in vegetable crops*. New India Publ. Agency.

Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi.

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Simmonds NW. 1978. *Principles of crop improvement*. Longman. Singh BD. 1983. Plant Breeding. Kalyani Publishers, New Delhi.

Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. International Book Distributing Co.

Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

I. Course Title : Biodiversity and Conservation of Vegetable Crops

II. Course Code : VSC 606

III. Credit Hours : (2+1)

IV. Why this course ?

The availability of pertinent gene pool is of utmost importance to mitigate adverse climate and to counter diseases and pests. In addition, specific gene sources (germplasm) would always be necessary to develop superior genotypes. Considering the importance of conserving biodiversity in vegetable crops for future use, the course has been designed.

V. Aim of the course

To understand the status and magnitude of biodiversity and strategies in germplasm conservation of vegetable crops.

The course is organised as follows:

No.	Blocks	Units
1	Biodiversity and conservation of vegetable crops	I General Aspects: Issues, Goals and Current Status II. Germplasm Conservation: Collection, Maintenance and Characterization III. Regulatory Horticulture: Germplasm Exchange, Quarantine and Intellectual Property Rights

VI. Theory

Unit I

General aspects: issues, goals and current status: Biodiversity and conservation; issues and goals- needs and challenges; present status of gene centres; world's major centres of fruit crop domestication; current status of germplasm availability/ database of fruit crops in India

Unit II

Germplasm conservation: collection, maintenance and characterization: Exploration and collection of germplasm; sampling frequencies; size and forms of fruit and nut germplasm collections; active and base collections. Germplasm conservation- in situ and ex situ strategies, on farm conservation; problem of recalcitrance- cold storage of scions, tissue culture, cryopreservation, pollen and seed storage.

Unit III

Regulatory horticulture: Germplasm exchange, quarantine and intellectual property rights germplasm exchange, quarantine and intellectual property rights regulatory horticulture, inventory and exchange of fruit and nut germplasm, plant quarantine, phytosanitary certification, detection of genetic constitution of germplasm and maintenance of core collection. IPRs, Breeder's rights, Farmer's rights, PPVandFR Act. GIS and documentation of local biodiversity, Geographical indications, GIS application in horticultural mapping and spatial analyses of field data; benefits of GI protection; GI tagged fruit varieties in India.

VII. Practical

- Documentation of germplasm- maintenance of passport data and other records of accessions;
- Field exploration trips and sampling procedures;
- Exercise on *ex situ* conservation – cold storage, pollen/ seed storage
- Cryopreservation;
- Visits to national gene bank and other centers of PGR activities;
- Detection of genetic constitution of germplasm;
- Germplasm characterization using a standardised DUS test protocol;
- Special tests with biochemical and molecular markers.

VIII. Teaching Methods/ Activities

- Class room lectures
- Laboratory/ field practicals
- Student seminars/ presentations
- Field tours/ demonstrations
- Assignments

IX. Learning outcome

- The student would be expected to learn about the significance of germplasm
- Various strategies to conserve it in the present context.

X. Suggested Reading

Dhillon BS, Tyagi RK, Lal A and Saxena S. 2004. *Plant genetic resource management. – horticultural crops*. Narosa publishing house, New Delhi.

Engles JM, Ramanath RV, Brown AHD and Jackson MT. 2002. *Managing plant genetic resources*, CABI, Wallingford, UK.

Frankel OH and Hawkes JG. 1975. *Crop genetic resources for today and tomorrow*. Cambridge University Press, USA.
Hancock J. 2012. *Plant evolution and the origin of crops species*. CAB International.
Jackson M, Ford-Lloyd B and Parry M. 2014, *Plant genetic resources and climate change*. CABI, Wallingford, UK
Moore JN and Ballington JR. 1991. *Genetic resources of temperate Fruit and nut crops*. ISHS, Belgium.
Peter KV. 2008. *Biodiversity of horticultural crops*. Vol. II. Daya Publ. House, Delhi.
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Sthapit *et al*. 2016. *Tropical fruit tree diversity (good practices for in situ and ex situ conservation)*. Bioversity international. routledge, Taylor and Francis Group.
Virchow D. 2012. *Conservation of genetic resources*, Springer Verlag, Berlin

I. Course Title : Biotechnological Approaches in Vegetable Crops

II. Course Code : VSC 607

III. Credit Hours : (2+1)

IV. Why this course ?

Biotechnology is a rapidly developing area of contemporary science. It can bring new ideas, improved tools and novel approaches to the solution of some persistent, seemingly intractable problems in vegetable production. Given the pressing need to enhance and stabilize the vegetable production in response to mounting population pressures and increasing awareness, there is an urgent need to explore novel technologies that will break traditional barriers.

V. Aim of the course

To impart latest knowledge in biotechnical advancement in vegetable crops

The course is organised as follows:-

No.	Blocks	Units
1	Biotechnological approaches in vegetable crops	I Importance and scope of Biotechnology II Somatic embryogenesis III Blotting techniques, DNA finger printing, IV Plant genetic engineering V Concepts and methods of next generation sequencing (NGS)

VI. Theory

Unit I

Importance and scope of biotechnology – in vegetable crop improvement. *In-vitro* culture, micropropagation, anther culture, pollen culture, ovule culture, embryo culture, endosperm culture.

Unit II

Somatic embryogenesis – somaclonal variation and synthetic seed production, protoplast isolation, culture, manipulation and fusion. Somatic hybrids and cybrids and their application in vegetable improvement programme.

Unit III

Blotting techniques, DNA finger printing – Molecular markers/ DNA based markers and role. RFLP, AFLP, RAPD, SSR, SNPs, DNA probes. QTL mapping. MAS and its application in vegetable crop improvement. Allele mining by TILLING and Eco-TILLING.

Unit IV

Plant genetic engineering – Scope and importance, Concepts of cisgenesis, intragenesis and transgenesis. Gene cloning, direct and indirect methods of gene transfer. Role of RNAi based gene silencing in vegetable crop improvement. Bio-safety issue, regulatory issues for commercial approval.

Unit V

Concepts and methods of next generation sequencing (NGS)- Genome sequencing, transcriptomics, proteomics, metabolomics. Genome editing (ZFN, TALENS and CRISPER)

Crops

Solanaceous crops, cole crops, cucurbitaceous crops, root vegetables, garden pea, onion, potato and leafy vegetables

VII. Practical

- Micropropagation, Pollen- Ovule and Embryo culture- Synthetic seed production (2);
- *In-vitro* mutation induction, *in-vitro* rooting – hardening at primary and secondary nurseries (3);
- DNA isolation from economic vegetable crop varieties – Quantification and amplification (2);
- DNA and Protein profiling – molecular markers, PCR Handling (2);
- Vectors for cloning and particle bombardment (3);
- DNA fingerprinting of flower crop varieties (3);
- Project preparation for establishment of low, medium and high cost tissue culture laboratories (1).

VIII. Teaching Methods/ Activities

- Class room lectures
- Laboratory/ field practicals
- Student seminars/ presentations
- Field tours/ demonstrations
- Assignments

IX. Learning outcome

The student would be expected to learn

- Different biotechnological tools
- NGS, genetic engineering

X. Suggested Reading

Bajaj YPS. (Ed.). 1987. *Biotechnology in agriculture and forestry*. Vol. XIX. Hitech and Micropropagation. Springer.

Chadha KL, Ravindran PN and Sahijram L. (Eds.). 2000. *Biotechnology of horticulture and plantation crops*. Malhotra Publ. House.

Debnath M. 2005. *Tools and techniques of biotechnology*. Pointer publication, New Delhi.

Glover MD. 1984. *Gene cloning: the mechanics of DNA manipulation*. Chapman and Hall.
Gorden H and Rubsell S. 1960. *Hormones and cell culture*. AB Book Publ.
Keshavachandran R. 2007. *Recent trends in biotechnology of horticultural crops*. New India Publ. Agency.
Keshavachandran R and Peter KV. 2008. *Plant biotechnology; tissue culture and gene transfer*. Orient and Longman, USA.
Keshavachandran R. 2007. *Recent trends in biotechnology of horticultural crops*. New-India Publication Agency, New Delhi.
Panopoulas NJ. (Ed.). 1981. *Genetic engineering in plant sciences*. Praeger Publ.
Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK and Mohanadas S. 2001. *Biotechnology of horticultural crops*. Vols. I-III. Naya Prokash.
Pierik RLM. 1987. *In-vitro culture of higher plants*. Martinus Nijhoff Publ.
Prasad S. 1999. *Impact of plant biotechnology on horticulture*. 2nd Ed. Agro Botanica.
Rout GR and Peter KV. 2018. *Genetic engineering of horticultural crops*. Academic Press Elsveer, USA.
Sharma R. 2000. *Plant tissue culture*. Campus Books.
Singh BD. 2010. *Biotechnology- expanding horizons*. Kalyani Publishers, New Delhi.
Skoog Y and Miller CO. 1957. *Chemical regulation of growth and formation in plant tissue cultured in-vitro*. Attidel. II Symp. On biotechnology action of growth substance.
Vasil TK, Vasi M, While DNR and Bery HR. 1979. *Somatic hybridization and genetic manipulation in plants, plant regulation and world agriculture*. Planum Press.

I. Course Title : Advanced Laboratory Techniques for Vegetable Crops

II. Course Code : VSC 608

III. Credit Hours : (1+2)

IV. Why this course ?

Accurate quality analysis of vegetables warrants stringent measurement protocols besides requisite instruments/ tools and laboratory facilities. Consequently, a specialized course is designed for imparting basic and applied training on physical and biochemical assessment of the vegetable produce.

V. Aim of the course

To familiarize with the laboratory techniques for analysis of vegetable crops.

The organisation of the course is as under:

No.	Blocks	Units
1	Advanced laboratory techniques for vegetable crops	I Safety measures and laboratory maintenance II Qualitative and quantitative analysis destructive and non-destructive analysis methods III Chromatographic and microscopic analysis IV Sensory analysis

VI. Theory

Unit I

Safety measures and laboratory maintenance – Safety aspects and upkeep of laboratory, sampling procedures for quantitative analysis, determination of proximate composition of horticultural produce. Standard solutions, determination of relative water content (RWC), physiological loss in weight (PLW), calibration and standardization of instruments, textural properties of harvested produce, TSS, Specific gravity, pH and acidity.

Unit II

Destructive and non-destructive analysis methods – Refractometry, spectrophotometry, non-destructive determination of colour, ascorbic acid, sugars, and starch in food crops.

Unit III

Chromatographic and microscopic analysis- basic chromatographic techniques, GC, HPLC, GCMS, Electrophoresis techniques, ultra filtration. Application of nuclear techniques in harvested produce. Advanced microscopic techniques, ion leakage as an index of membrane permeability, determination of biochemical components in horticultural produce.

Unit IV

Sensory analysis – Importance of ethylene, quantitative estimation of rate of ethylene evolution, using gas chromatograph (GC). Sensory analysis techniques, control of test rooms, products and panel.

VII. Practical

- Determination of moisture, relative water content and physiological loss in weight;
- Determination of biochemical components in horticultural produce;
- Calibration and standardization of instruments;
- Textural properties of harvested produce;
- Determination of starch index (SI);
- Specific gravity for determination of maturity assessment, and pH of produce;
- Detection of adulterations in fresh as well as processed products;
- Non-destructive determination of colour, ascorbic acid, vitamins, carotenoids, sugars and starch;
- Estimation of rate of ethylene evolution using gas chromatograph (GC);
- Use of advanced microscopes (fluorescent, scanning electron microscope, phase contrast, etc.).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The students would be expected to develop skills and expertise on

- Upkeep of laboratories and handling of research instruments
- Principles and methods of various analysis

X. Suggested Reading

AOAC International. 2003. *Official methods of analysis of AOAC international*. 17th Ed. Gaithersburg, MD, USA, association of analytical communities, USA.

Clifton M and Pomeranz Y. 1988. *Food analysis – laboratory experiments*. AVI publication, USA.

Linskens HF and Jackson JF. 1995. *Fruit analysis*. Springer.

Leo ML. 2004. *Handbook of food analysis*, 2nd Ed. Vols. I-III, USA.
Pomrenz Y and Meloan CE. 1996. *Food analysis – theory and practice*. CBS, USA.
Ranganna S. 2001. *Handbook of analysis and quality control for fruit and vegetable products*. 2nd Ed. Tata-McGraw-Hill, New Delhi.
Thompson AK. 1995, *Postharvest technology of fruits and vegetables*. Blackwell sciences. USA.

Selected Journals

Sr. No.	Name of the Journal	ISSN No.
1.	*American Journal of Horticultural Sciences*	0003-1062
2.	*American Potato Growers*	
3.	*American Scientst*	1545-2786
4.	*Annals of Agricultural Research*	9703179
5.	*Annual Review of Plant Physiology*	0066-4294
6.	*California Agriculture*	1097-0967
7.	*Haryana Journal of Horticultural Sciences*	0970-2873
8.	*HAU Journal of Research*	0379-4008
9.	*Horticulture Research*	2052-7276
10.	*HortScience*	2327-9834
11.	*IIVR Bulletins*	1462-0316
12.	*Indian Horticulture*	0019-4875
13.	*Indian Journal of Agricultural Sciences*	0019-5022
14.	*Indian Journal of Horticulture*	0974-0112
15.	*Indian Journal of Plant Physiology*	2662-2548
16.	*Journal of American Society for Horticutural Sciences*	0003-1062
17.	*Journal of Arecanut and Spice Crops*	
18.	*Journal of Food Science and Technology*	0975-8402
19.	*Journal of Plant Physiology*	0176-1617
20.	*Journal of Biology and Technology*	0925-5214
21.	*Postharvest Biology and Technology*	0925-5214
22.	*Scientia Horticulturae*	0304-4238
23.	*Seed Research*	2151-6146
24.	*Seed Science*	23171537
25.	*South Indian Horticulture*	0038-3473
26.	*Vegetable Grower*	2330-2321
27.	*Vegetable Science*	2455-7552

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Horticultural Sciences
– Floriculture and Landscaping

Preamble
(Floriculture and Landscaping)

Indian floriculture which remained homestead farming till late 80's assumed commercial significance during 90's owing to the favourable environment created by a series of reforms in economy and seed sector. This has paved the way for the import of new plant material, introduction of protected cultivation technology in the country. The area under flower crops got almost tripled from 1,06,000 ha during 2001–02 to 3,39,000 ha during 2018–19. Similar trend was also noticed in production of flowers in India with an overall production of 19.91 lakh tonnes. India's total export of floriculture was ₹ 571.38 Crores/ 81.94 USD Millions in 2018–19. The major importing countries were United States, Netherlands, United Kingdom, Germany and United Arab Emirates.

Contrary to belief, floriculture encompasses a large number of sub sectors that include loose flowers, cut flowers, cut foliage, specialty flowers, cut greens and fillers, pot plants, bedding plants, landscaping and interiorscaping, vertical gardening, dry flowers, lawns, arboriculture, essential oils, nutraceutical pigments, dyes, value addition, etc., Keeping in pace with the latest developments in these sectors, there is a need to update the knowledge among the students. An effort is therefore made to encompass the advances made in the sector by revising the post-graduate curriculum.

New courses like Systematics of ornamental plants; Indoor plants and Interioscaping, Nursery Management of ornamental plants; Turf grass management; Seed production in flower crops; Crop regulation in ornamental crops; Speciality flowers, fillers and cut greens; Vertical gardening; Modern approaches in breeding of floricultural crops; Current trends in production of floricultural crops; Recent developments in protected cultivation of floricultural crops are introduced in the new syllabus while retaining some of the old courses.

Keeping in view of the National Initiatives and priorities like Skill India and emphasis on StartUps to encourage students to become job creators rather than job seekers, new courses are added in different avenues of floriculture like Indoor plants and Interioscaping, Nursery management, Turfgrass management, Vertical gardening. These courses will help and encourage students to develop their skills and would pave way for different StartUps in these areas.

New courses like seed production in flower crops, Crop regulation in ornamental crops, Specialty flowers, fillers and cut greens are introduced in line with requirement to improve profitability of farmers/ growers. Seed production in flowers which is a high value, low volume segment was focussed upon which will boost our exports and help in improving profitability and improving farmers income. Crop regulation is an important aspect and need of the hour to avoid market glut, improve profitability and income of growers.

Rapid changes and development have occurred in global arena particularly in the field of biochemistry, molecular biology and biotechnology. Many advances took place in the area of application of biotechnology approaches in flower crops. A segment on genome editing systems/ tools like CRISPR-CAS is introduced into the syllabus keeping in view of the recent developments. Several new developments in the area of protected cultivation like automation, sensors, lighting, AI, robotics, retractable greenhouses, IPR, flower labels, etc. are given due emphasis in the new syllabus.

Flowers are highly perishable and fluctuation of prices is very high and marketing is a very crucial step where growers and entrepreneurs face problems. Topics on marketing, Agri export Zones, value chain and cold chain management and crop insurance were given importance. Government of India has introduced a number of schemes and mechanisms to support the farming community. To make the students aware about the recent steps taken by Government, topic on Institutional support is introduced. Farming community is rapidly diversifying in to areas like FPO's and contract farming and these areas are introduced.

Course Title with Credit Load
M.Sc. (Hort.) in Floriculture and Landscaping

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
FLS 501*	Systematics of Ornamental Plants	2+1
FLS 502*	Breeding of Ornamental Plants	2+1
FLS 503*	Commercial Production of Cut Flowers	2+1
FLS 504*	Commercial Production of Loose Flowers	2+1
FLS 505*	Ornamental Gardening and Landscaping	2+1
FLS 506	Indoor Plants and Interiorscaping	1+1
FLS 507	Nursery Management in Ornamental Plants	2+1
FLS 508	Turf Grass Management	2+1
FLS 509	Value Addition in Floriculture	2+1
FLS 510	Protected Cultivation of Flower Crops	2+1
FLS 511	CAD for Landscaping	1+2
FLS 512	Seed Production in Flower Crops	1+1
	Minor Courses	08
	Supporting Courses	06
	Common compulsory courses	05
FLS 591	Seminar	0+1
FLS 599	Research	0+30
	Total Credits	**70**

*Compulsory among major courses

Course Contents
M.Sc. (Hort.) in Floriculture and Landscaping

I. Course Title : Systematics of Ornamental Plants

II. Course Code : FLS 501

III. Credit Hours : (1+1)

IV. Why this course ?

Systematics of ornamental plants will give an in depth knowledge on nomenclature, description of genera, floral biology and use of molecular techniques in systematics of flower crops and ornamental crops.

V. Aim of the course

To familiarize students about the taxonomy, classification, nomenclature and descriptors of different ornamental crops.

The course is organized as follows

No	Blocks	Units
1	Nomenclature	Unit 1: History, origin, hotspots, classification and nomenclature systems Unit 2: International Code, Identification features, descriptors. Unit 3: Red Book, Registration with NBPGR, PPVFRA
2	Families	Unit 1: Rosaceae, Asteraceae, Caryophyllaceae, Orchidaceae, Aracaeae, Liliacaeae, Unit 2: Acanthaceae, Palmaceae, Asparagaceae, Malvaceae, Musaceae, Oleaceae, Iridaceae.
3	Molecular techniques systematics.	Unit 1: Molecular techniques in modern

VI. Theory

Block I: Nomenclature

Unit I: Nomenclature: History, origin, hotspots, classification and nomenclature systems.

Unit II: International systems: International Code, Treaties, International and National Organisations, Biodiversity Act, Identification features, descriptors.

Unit III: Red Book, Registration (NBPGR, PPVFRA, NBA).

Block 2: Families

Unit I: Families: Description and families and important genera Rosaceae, Asteraceae, Caryophyllaceae, Orchidaceae, Aracaceae, Liliacae.

Unit II: Acanthaceae, Palmaceae, Asparagaceae, Malvaceae, Musaceae, Oleaceae, Iridaceae.

Block 3: Molecular techniques

Unit I: Molecular techniques in modern systematics.

VII. Practical

- Different nomenclature systems of plants (2);
- Floral biology and taxonomic description of rose, chrysanthemum, orchids, carnation, gerbera, anthurium, marigold, tuberose, Jasmine, China aster, lilium, gypsophila (6);
- Cyropreservation and tissue culture repository (4);
- Molecular techniques (4).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and student presentation
- Hands on training of different procedures

IX. Learning outcome

After successful completion of this course,

- The students will have an in depth knowledge of nomenclature, description of important genera and use of molecular techniques in systematics of flower crop

X. Suggested Reading

Bhattacharya B and Johri BM. 2004. *Flowering Plants: Taxonomy and Phylogeny*. Narosa Publ. House, New Delhi, India. pp.753.
Dutta AC. 1986. *A Class Book of Botany*. Oxford Univ. Press, Kolkata, India.
Pandey BP. 2013. *Taxonomy of Angiosperms*. S. Chand & Co. pp. 608.
Rajput CBS and Haribabu RS. 2014. *Citriculture*, Kalyani Publishers, New Delhi, India.
Spencer RR, Cross R and Lumley P. 2007. *Plant Names*. 3rd Ed. *A Guide to Botanical Nomenclature*. CSIRO Publ., Australia., 176 p.
Vasistha BB. 1998. *Taxonomy of Angiosperms*. Kalyani Publishers, New Delhi, India.

I. Course Title : Breeding of Ornamental Crops

II. Course Code : FLS 502

III. Credit Hours : (2+1)

IV. Why this course ?

Breeding novel and desired varieties is very important for growth of floriculture Industry. Students should have a thorough understanding of principles of plant breeding, genetic mechanisms and breeding methods in ornamental crops for making improvement in these crops.

V. Aim of the course

To impart comprehensive knowledge about the principles and practices of breeding of ornamental plants.

The course is organized as follows

No	Blocks	Units
1	Principles of Plant Breeding	I. Principles of plant breeding II. Intellectual Property and Plant Breeders Rights III. Genetic mechanisms and inheritance
2	Breeding methods	I. Breeding methods II. Role of biotechnology

VI. Theory

Block 1: Principles of Plant Breeding

Unit I: Principles of plant breeding: Principles of plant breeding; Origin, evolution, distribution, introduction, domestication and conservation of ornamental crops.

Unit II: Intellectual Property and Plant Breeders Rights: Introduction and initiatives in IPR and PBR of ornamental crops.

Unit III: Genetic mechanisms and inheritance: Breeding objectives, reproductive barriers (Male sterility, incompatibility) in major ornamental crops. Inheritance of important traits, Genetic mechanisms associated with flower colour, size, form, doubleness, fragrance, plant architecture, post-harvest life, abiotic and biotic stress tolerance/ resistance.

Block 2: Breeding methods

Unit I: Breeding methods: Breeding methods suitable for sexually, asexually propagated flower crops, self and cross pollinated crops- pedigree selection, backcross, clonal selection, polyploidy and mutation breeding, heterosis and F1 hybrids.

Unit II: Role of biotechnology: Role of biotechnology in improvement of flower crops including somaclonal variation, *in-vitro* mutagenesis, *in-vitro* selection, genetic engineering, molecular markers, etc.

Crops

Rose, chrysanthemum, carnation, gerbera, gladiolus, orchids, anthurium, lilium, marigold, jasmine, tuberose, dahlia, gaillardia, crossandra, aster, etc., Flowering annuals: petunia, zinnia, snapdragon, stock, pansy, calendula, balsam, dianthus, etc. Important ornamental crops like aglaonema, diffenbachia, hibiscus, bougainvillea, kalanchoe, etc.

VII. Practical

- Floral biology of important ornamental crops (2);
- Cytology and cytogenetics (2);
- Selfing and crossing procedures for important ornamental crops (2);
- Evaluation of hybrid progenies (2);
- Induction of mutants through physical and chemical mutagens (2);
- *In-vitro* selection, genetic engineering (2);
- Induction of polyploidy (2);
- DUS testing (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and student presentation
- Hands on training of different procedures

IX. Learning outcome

After successful completion of course, the students are expected to have

- Thorough understanding of principles of plant breeding and genetic mechanisms in different ornamental plants and flowers.
- Application of different breeding methods for improvement of ornamental crops
- Develop the required skills in conventional and advanced breeding

X Suggested Reading

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Pointer Publ., Reprint, 6 vols, pp. 2065.

Bose TK and Yadav LP. 1989. *Commercial flowers*. Naya Prokash, Kolkata, India.

Callaway DJ and Callaway MB. 2009. *Breeding Ornamental Plants*. Timber Press. Revised edition, pp. 359.

Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants*. Vol. XII, Parts 1 & 2. pp. 533, pp. 574. Malhotra Publ. House, New Delhi, India.

Chadha KL and Choudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.

Chaudhary RC. 1993. *Introduction to Plant Breeding*. Oxford & IBH Publ.

Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Cut Flowers*. Kruger Brentt Publisher UK Ltd. pp.584.

Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Traditional and Loose Flowers*. Kruger Brentt Publisher UK Ltd.

Singh BD. 2016. *Plant Breeding Principles and Methods*. Kalyani Publishers, New Delhi-Ludhiana, India.

Vainstein A. (Ed). 2002. *Breeding for ornamental crops: Classical and Molecular Approaches*. Springer-Science-Business Media, B.V. Edition 1. pp. 392.

Watts L. 1980. *Flower and Vegetable Plant Breeding*. Unilever Research, Sharnbrook, Bedford, UK. pp 182. Grower Books, London, UK.

I. Course Title : Commercial Production of Cut Flowers

II. Course Code : FLS 503

III. Credit Hours : (2+1)

IV. Why this course ?

Cut flowers are grown in a wide variety of environments and agroclimatic regions. The students of floriculture need to have an understanding of production and post harvest management of important cut flower crops on a commercial scale.

V. Aim of the course

To impart basic knowledge about the importance and production dynamics of cut flowers grown in India.

The course is organized as follows

No	Blocks	Units
1	Production management	I. Scope and scenario II. Growing environment

No	Blocks	Units
		III. Crop Management IV. Flower regulation
2	Post harvest management and marketing	I. Post harvest management II. Marketing

VI. Theory

Block 1: Production management

Unit I: Scope and scenario: National and International scenario, importance and scope of cut flower trade, constraints for cut flower production in India.

Unit II: Growing environment: Soli analysis, soil health card, Growing environment, open cultivation, protected cultivation, soil/ media requirements, land preparation, planting methods, influence of light, temperature, moisture, humidity and microclimate management on growth and flowering.

Unit III: Crop management: Commercial Flower production – Commercial varieties, water and nutrient management, fertigation, weed management, crop specific practices, ratooning, training and pruning, pinching, deshooting, bending, desuckering, disbudding. Use of growth regulators, physiological disorders and remedies, IPM and IDM.

Unit IV: Flower regulation: Flower forcing and year round/ offseason flower production through physiological interventions, chemical regulation, environmental manipulation.

Block 2: Post-harvest management and marketing

Unit I: Post harvest management: Cut flower standards and grades, harvest indices, harvesting techniques, post-harvest handling, Methods of delaying flower opening, Pre-cooling, pulsing, packing, storage and transportation.

Unit II: Marketing: Marketing, export potential, institutional support, Agri Export Zones, 100% Export Oriented units, Crop Insurance.

Crops

Rose, chrysanthemum, gladiolus, tuberose, carnation, gerbera, orchids, lilium, anthurium, china aster, alstroemeria, bird of paradise, heliconia, alpinia, ornamental ginger, dahlia, gypsophila, solidago, limonium, stock, cut greens and fillers.

VII. Practical

- Identification of varieties (1);
- Propagation (2);
- Microclimate management (2);
- Training and pruning techniques (1);
- Pinching, deshooting, disbudding, desuckering (1);
- Practices in manuring, drip and fertigation, foliar nutrition, growth regulator application (2);

- Harvesting techniques, post-harvest handling, cold chain (2);
- Economics, Project preparation for regionally important cut flowers, crop specific guidelines for project financing (NHB guidelines) (2);
- Visit to commercial cut flower units (2);
- Case studies (1).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and student presentation
- Hands on training of different procedures
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to–

- Understand the scope and scenario of floriculture
- A thorough understanding of production and post harvest management of flower crops.
- Acquire the required skills to prepare project reports on different crops for financing.

X. Suggested Reading

Arora JS. 2010. *Introductory Ornamental Horticulture*. Kalyani Publishers. 6th edition, pp. 230.

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.

Bose TK, Maiti, RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Prokash, Kolkata, India.

Bose TK and Yadav LP. 1989. *Commercial Flowers*. Naya Prokash, Kolkata, India.

Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants*. Vol. XII, Parts 1 & 2. pp. 533, pp. 574. Malhotra Publ. House, New Delhi, India.

Chadha KL and Chaudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.

Dole JM and Wilkins HF. 2004. *Floriculture-Principles and Species*. Prentice Hall. 2nd edition, pp. 1048.

Larson RA. 1980. *Introduction to Floriculture*. New York Academic Press. pp. 628.

Laurie A and Rees VH. 2001. *Floriculture-Fundamentals and Practices*. Agrobios Publications, Jodhpur. pp.534.

Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publications, Jodhpur.

Randhawa GS and Mukhopadhyay A. 2001. *Floriculture in India*. Allied Publ. pp 660.

Reddy S, Janakiram T, Balaji Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India.

Singh AK. 2006. *Flower Crops: Cultivation and Management*. New India Publ. Agency, New Delhi, India. pp. 475.

I. Course Title : Commercial Production of Loose Flowers

II. Course Code : FLS 504

III. Credit Hours : (2+1)

IV. Why this course ?

Loose flowers are grown in a wide range of agroclimatic regions. The students of floriculture need to have an understanding of production and post harvest management of important loose flower crops.

V. Aim of the course

To impart basic knowledge about the importance and management of loose flowers grown in India.

The course is organized as follows

No	Blocks	Units
1	Production management	I. Scope and scenario II. Growing environment III. Crop management IV. Flower regulation
2	Post harvest management and marketing	I. Post harvest management II. Marketing

VI. Theory

Block 1: Production management

Unit I: Scope and scenario: Scope, scenario and importance of loose flowers, constraints and opportunities in loose flower production.

Unit II: Growing environment: Nursery management, pro-tray nursery under shade nets, soil and climate requirement, Field preparation, systems of planting.

Unit III: Crop management: Soli analysis, soil health card, water and nutrient management, weed management, training and pruning, special horticultural practices such as pinching and disbudding, use of growth regulators, physiological disorders and remedies, INM, IPM and IDM.

Unit IV: Crop regulation: Flower forcing and year round flowering, production for special occasions through physiological interventions, chemical regulation.

Block 2: Post harvest management and marketing

Unit I: Post harvest management: Harvest indices, harvesting techniques, post-harvest handling and grading, pre-cooling, packaging and storage.

Unit II: Marketing: Important local markets, Export potential, transportation and marketing, APMC and online trading, institutional support, Crop Insurance.

Crops

Rose, jasmine, chrysanthemum, marigold, tuberose, china aster, crossandra, gaillardia, spider lily, hibiscus, nerium, barleria, celosia, gomphrena, Madar (*Calotropis gigantea*), nyctanthes (Harsingar), tabernaemontana (Chandni), lotus, water lily, michelia (Champa), gardenia, ixora and balsam.

VII. Practical

- Identification of species and varieties (1);
- Propagation and nursery management (1);
- Training and pruning techniques (1);
- Fertigation, foliar nutrition, growth regulator application (2);

- Crop protection (2);
- Pinching, disbudding, staking, harvesting techniques (1);
- Post-harvest handling, storage and cold chain (2);
- Project preparation for regionally important commercial loose flowers. crop specific guidelines for project financing (NHB guidelines) (2);
- Cost Economics (2);
- Exposure Visits to fields (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students would have

- A thorough understanding of production and post harvest management of loose flowers.
- Develop the required skills on commercial production management

X. Suggested Reading

Arora JS. 2010. *Introductory Ornamental Horticulture*. Kalyani Publi. 6th Edition, pp. 230.
Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.
Bose T K, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and landscaping*. Naya Prokash, Kolkata, India.
Bose TK and Yadav LP. 1989. *Commercial Flowers*. Naya Prokash, Kolkata, India.
Chadha KL and Bhattacharjee S K. 1995. *Advances in Horticulture: Ornamental Plants*. Vol. XII, Parts 1 & 2. pp. 533, pp. 574. Malhotra Publ. House, New Delhi, India.
Chadha KL and Chaudhury B.1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.
Laurie A and Rees VH. 2001. *Floriculture-Fundamentals and Practices*. Agrobios Publ., Jodhpur. pp.534.
Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publ., Jodhpur.
Randhawa GS and Mukhopadhyay A. 2001. *Floriculture in India*. Allied Publ. pp 660.
Sheela VL. 2008. *Flowers for Trade*. Horticulture Science Series, vol.10, pp. 392. New India Publ. Agency, New Delhi, India.

I. Course Title : Ornamental Gardening And Landscaping

II. Course Code : FLS 505

III. Credit Hours : (2+1)

IV. Why this course ?

Ornamental gardening and landscaping is an important course which gives a thorough understanding of different types of gardens and their components. The students need to imbibe the principles of landscaping and should develop skills for planning under different situations.

V. Aim of the course

Familiarization with principles and practices of landscaping

The course is organized as follows

No	Blocks	Units
1	Gardens and components	I. Styles and types of gardens II. Garden components III. Specialized gardens
2	Landscape planning	I. Principles and elements of landscaping II. Landscaping for different situations

VI. Theory

Block 1: Gardens and components

Unit I: Styles and types of gardens: Historical background of gardening, Importance and scope of ornamental gardening, styles and types of gardens, formal and informal style gardens. English, Mughal, Japanese, Persian, Spanish, Italian, French, Hindu and Buddhist gardens.

Unit II: Garden components: Garden components (living and non-living): arboretum, shrubbery, fernery, palmatum, arches and pergolas, edges and hedges, climbers and creepers, cacti and succulents, herbs, annuals, flower borders and beds, ground covers, carpet beds, colour wheels, clock garden, bamboo groves, bonsai; Non -living components like-path, garden gate, fencing, paving and garden features like fountains, garden seating, swings, lanterns, basins, bird baths, sculptures, waterfalls, bridge, steps, ramps, Lawn -genera and species, establishment and maintenance.

Unit III: Specialized gardens: Specialised gardens such as vertical garden, roof garden, terrace garden, water garden, sunken garden, rock garden, shade garden, temple garden, sacred gardens (with emphasis on native plants), Zen garden.

Block 2: Landscape planning

Unit I: Principles and elements of landscaping: Basic drawing skills, use of drawing instruments garden symbols, steps in preparation of garden design, programmes phase, design, phase, etc.

Elements and principles of landscape design. Organization of spaces, visual aspects of plan arrangement- view, vista and axis. Principles of circulation, site analysis and landscape, water requirement, use of recycled water.

Unit II: Landscaping for different situations: Urban landscaping, Landscaping for specific situations such as residential, farm houses, institutions, corporate sector, industries, hospitals, roadsides, traffic islands, Children parks, public parks, xeriscaping, airports, railway station and tracks, river banks and dam sites and IT/ SEZ parks. Bio-aesthetic planning, eco-tourism, theme parks, indoor gardening, therapeutic gardening.

VII. Practical

- Graphic language and symbols in landscaping, study of drawing instruments, viz., 'T' square, setsquare, drawing board, etc. (1);
- Identification of various types of ornamental plants for different gardens and occasions (1);
- Preparation of land, planning, layout and planting, deviations from landscape principles (1);
- Case study (1);
- Site analysis, interpretation of map of different sites, use of GIS for selection (1);
- Enlargement from blue print. Landscape design layout and drafting on paper as per the scale (2);
- Preparation of garden models for home gardens, farm houses, industrial gardens, institutional gardens, corporate, avenue planting, practices in planning and planting of special types of gardens.(3);
- Burlapping, lawn making, planting of edges, hedges, topiary, herbaceous and shrubbery borders (2);
- Project preparation on landscaping for different situations, creation of formal and informal gardens (2);
- Visit to parks and botanical gardens (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training on different models of landscaping
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to be

- The students will be apprised of different types of gardens and have a thorough understanding of principles of landscape gardening
- Develop skills for landscaping under different situations and layout of garden components.

X. Suggested Reading

Bose TK, Chowdhury B and Sharma SP. 2011. *Tropical Garden Plants in Colour*. Hort. and Allied Publ.

Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.

Grewal HS and Singh P. 2014. *Landscape Designing and Ornamental Plants*. Kalyani Publishers, New Delhi.

Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices*.Agrobios Publ., Jodhpur.

Misra RL and Misra S. 2012. *Landscape Gardening*. Westville Publ. House, New Delhi, India.

Nambisan KMP. 1992. *Design Elements of Landscape Gardening*. Oxford & IBH Publ. Co., New Delhi, India.

Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.

Sabina GT and Peter KV. 2008. *Ornamental Plants for Gardens*. New India Publ. Agency, New Delhi, India.

Singh A and Dhaduk BK. 2015. *A Colour Handbook: Landscape Gardening*. New India Publ. Agency, New Delhi, India.

Valsalakumari PK, Rajeevan PK, Sudhadevi PK and Geetha CK. 2008. *Flowering Trees*. New India Publ. Agency, New Delhi, India.
Woodrow MG.1999. *Gardening in India*. Biotech Books, New Delhi, India.

I. Course Title : Indoor Plants and Interiorscaping
II. Course Code : FLS 506
III. Credit Hours : (1+1)

IV. Why this course ?

Indoor plants are an important component of floriculture. They not only improve the aesthetic environment of indoors but are also known to improve indoor air quality. The students in floriculture need up to date knowledge on factors affecting indoor growing, types, cultural operations and different principles of interiorscaping.

V. Aim of the course

To facilitate deeper understanding of the benefits of indoor plants, selection, designing and their management.

The course is organized as follows

No	Blocks	Units
1	Scope, principles and operations	I. Importance and scope II. Classification and principles III. Cultural operations
2	Presentations and marketing	I. Special gardens II. Vertical gardens III. Marketing

VI. Theory

Block 1: Scope, principles and operations

Unit I: Importance and scope: Importance and scope of indoor plants and Interiorscaping, Indoor plants and Indoor air quality.

Unit II: Classification and principles: Factors affecting growth, development and flowering of Indoor plants. Classification of indoor plants based on light, temperature, humidity and pollution tolerance, Description and cultivation of various indoor plants. Principles of Interiorscaping, Role in pollution mitigation.

Unit III: Cultural operations: Containers and substrates, preparation of growing media, propagation, training, grooming, nutrition, management of disease, pests and weeds. Maintenance of plants including repotting, foliar nutrition, light exposure and plant rotation. Media standards, Nursery and Export standards for potted plants, Nursery standards.

Block 2: Presentations and marketing

Unit I: Special gardens: Special gardens including miniature gardens and plant stand. Presentations like dish, terrarium, bottle gardens, hanging baskets, window boxes and Bonsai.

Unit II: Vertical gardens: Vertical gardens- History, planting material, structures, containers, substrate, water and nutrient management, supplemental lighting.

Unit III: Marketing: Marketing channels, Business models including plant rentals.

VII. Practical

- Identification of important house plants (2);
- Media and containers (1);
- Propagation (1);
- Cultural operations, maintenance and economics of indoor plants (2);
- Models for Interiorscaping (2);
- Familiarization with different indoor gardens (2);
- Making of terrariums, bottle garden, dish garden and their economics (2);
- Making of vertical gardens and economics (2);
- Exposure visits (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to develop

- Deep understanding and knowledge of principles affecting indoor cultivation including vertical gardens
- Develop required skills in interiorscaping
- Develop required entrepreneurial acumen

X. Suggested Reading

Barbara P. 2005. *The Complete Houseplant Survival Manual*. Storey Publ., New Adams.

Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.

Wallach C. 1995. *Interior Decorating with Plants*. McMillan Seed Production Co. Inc., New York.

I. Course Title : Nursery Management for Ornamental Plants

II. Course Code : FLS 507

III. Credit Hours : (2+1)

IV. Why this course ?

Nursery management is very essential for production of quality planting material in ornamental plants. The course gives a thorough understanding of propagation of different ornamental plants, nursery management, standards, law and certification.

V. Aim of the course

Familiarization with principles and practices of propagation and nursery management for Ornamental plants.

The course is organized as follows:

No	Blocks	Units
1	Nursery Industry and Propagation	I Scenario of nursery industry and sexual propagation II Asexual propagation III Micropropgation
2	Nursery Management	I Growing structures II Sanitary and phytosanitary issues III Standards

VI. Theory

Block 1: Nursery Industry and Propagation

Unit I: Scenario of nursery industry and sexual propagation: Importance and present scenario and status of nursery industry in India and in the world, life cycles in plants, Propagation methods, Factors influencing seed germination of flower crops, dormancy, seed quality, packing, storage, certification, testing. Hormonal regulation of germination and seedling growth.

Unit II: Asexual propagation: Methods of asexual propagation, rooting of soft and hard wood cutting under mist. Role of Plant growth regulators. Physiological, anatomical and biochemical aspects of root induction in cuttings. Layering – principles and methods, budding and grafting – selection of elite mother plants. Stock, scion and inter stock, relationship – Incompatibility.

Unit III: Micropropagation: Micro-propagation – principles and concepts, commercial exploitation in flower crops. Techniques – *in-vitro* clonal propagation, direct organogenesis, embryogenesis, micrografting, meristem culture. Hardening, packing and transport of micro-propagules.

Block 2: Nursery Management

Unit I: Growing structures: Growing structures like mist chambers, tunnels, lath house, net house, growing media types, soil less culture and containers. Automation in nursery management.

Unit II: Sanitary and phyto-sanitary issues: Nursery – types, components, planning and layout. Nursery management practices for healthy propagule production. Nursery Act, PPV&FR act and Quarantine system in India. Important quarantine pests and diseases, sanitary and phyto-sanitary issues threats to nursery Industry.

Unit III: Standards: Nursery standards, Hi-tech nurseries, garden centers.

VII. Practical

- Anatomical studies in rooting of cutting and graft union (2);
- Identification and production of plug plants, seedlings and saplings (2);
- Preparation of growing media and use of PGRs (2);
- Practice of propagation through specialized structures cuttings, layering, budding and grafting (2);
- Case studies (2);

- Micropropagation of ornamental crops and hardening (3);
- Visit to tissue culture labs and nurseries (2);
- Economics (1).

VIII. Teaching Methods/ Activities
- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,
- The students will develop thorough understanding of nursery management in flower crops.
- Empower the students with the knowledge to start an enterprise
- Hone adequate skill in propagation and management

X. Suggested Reading

Adriance GW and Brison FR. 2000. *Propagation of Horticultural Plants*. Biotech Books, New Delhi, India.

Bose TK, Mitra SK and Sadhu M K. 1991. *Propagation of Tropical and Subtropical Horticultural Crops*. Naya Prokash, Kolkata, India.

Chadha KL, Ravindran PL and Leela Sahijram. 2000. *Biotechnology in Horticulture and Plantation Crops*. Malhotra Publ. House, New Delhi, India.

Davies Fred T Jr., Geneve RL, Wilson SB, Hartmann HT and Kester DL. 2018. *Hartmann and Kester's Plant Propagation: Principles and Practices.* Pearson Publ. 9th Edition.

Peter KV. 2008. *Basics of Horticulture*. New India Publ. Agency, New Delhi, India.

Rajan S and Baby LM. 2007. *Propagation of Horticultural Crops*. New India Publ. Agency, New Delhi, India. pp. 251.

Singh SP. 1989. *Mist Propagation*. Metropolitan Book Co., New Delhi, India.

I. Course Title : Turfgrass Management

II. Course Code : FLS 508

III. Credit Hours : (2+1)

IV. Why this course ?

Turf grass management deals with establishment and maintenance of different turf grasses for aesthetic, recreational and sports purposes. The course deals with basic types, requirement of turf grasses, management and development of turf for different purposes.

V. Aim of the course

To understand the science, principles and management of turf grasses.
The course is organized as follows:

No	Blocks	Units
1	Turf Industry and turf management	I Prospects and basic requirement
		II Types of turf grasses
		III Operations and management
2	Turf for different ground	I Making of different sports arenas
		II Automation in turf management

VI. Theory

Block 1: Turf industry and turf grasses

Unit I: Prospects and basic requirement: History, present status and prospects of turf industry; basic requirements, site selection and evaluation, concepts of quality of soil pertaining to turf grass establishment, criteria for evaluation of turf quality.

Unit II: Types of turf grasses: Types, species, varieties, important breeders, grasses for different locations and conditions and their compatible groupings as per climatic conditions; Turfing for roof gardens.

Unit III: Operations and management: Preparatory operations; Turf establishment methods such as seeding, sprigging/ dibbling, plugging, sodding/ turfing, turf plastering, instant turfing (portable), hydro-seeding, synthetic turfing. Turf management – Irrigation, drainage, nutrition, special practices like aerating, rolling, coring, dethatching, verticutting, soil top dressing, use of plant growth regulators and micronutrients, Turf mowing – mowing equipments, techniques to minimize wear and compaction, weed control, biotic and abiotic stress management in turfs, standards for turf, use of recycled water, etc.

Block 2: Turf for different grounds

Unit I: Making of different sports arenas: Establishment and maintenance of turfs for playgrounds, viz., golf, football, hockey, cricket, tennis, rugby, residential and public parks, turfing of Govt. and Corporate office gardens, event specific preparation, turf colourants.

Unit II: Automation: Exposure to different tools, gadgets, machinery used in turf industry.

VII. Practical

- Identification of turf grasses and turf machinery (1);
- Soil preparation, turf establishment methods, provision of drainage (2);
- Layout of macro and micro irrigation systems (1);
- Water and nutrient management (2);
- Special practices – mowing, raking, rolling, soil top dressing, weed management (2);
- Biotic and abiotic stress management (2);
- Project preparation for turf establishment (2);
- Visit to parks, model cricket grounds and golf courses, airports, corporates, Govt. organizations (2);
- Rejuvenation of lawns (1);
- Turf economics (1).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to

- Deep understanding and knowledge of different types of grasses and their management
- Developing skills for turfing of different arenas
- Develop required entrepreneurial acumen

X. Suggested Reading

Aldous D.1999. *International Turf Management Handbook.* CRC Press. pp.368.

Beard JB. 1972. *Turf Grass Science and Culture*. Pearson. 1st edition, pp. 672.

Chawla SL, Patil S, Patel MA, Patel RB and Patel RM. 2013. *Turf grass Management*. Publised by NAU, Navsari.

Emmons R. 2007. *Turf grass Science and Management.* Cengage Learning Publ. 4th edition, pp. 592.

Nick-Christians. 2011. *Fundamentals of Turf grass Management*. Wiley; 4th Edition, pp. 424.

Turgeon AJ. 1980. *Turf grass Management*. Reston Publ. Inc.

I. Course Title : Value Addition in Floriculture

II. Course Code : FLS 509

III. Credit Hours : (2+1)

IV. Why this course ?

Value addition is done to increase the economic value of any floriculture commodity. Students need to develop thorough understanding of scope, scenario and different methods of value addition so that they can improve the income of the stakeholders by value addition.

V. Aim of the course

To understand the avenues for value addition in floriculture

The course is organized as follows:

No	Blocks	Units
1	Value added products	I Scope and scenario II Value addition of loose flowers III Floral Arrangements IV Dry flowers
2	Extraction of value added products	I Essential oils II Pigments and nutraceuticals

VI. Theory

Block 1: Value added products

Unit I: Scope and scenario: Scope and prospects of value addition, National and global scenario, production and exports. Types of value added products, techniques of value addition including tinting.

Unit II: Value addition in loose flowers: Value addition in loose flowers and product development- Gulkhand, floral tea, rose oil, rose water, Pankhuri, floral dyes, rose sherbet, floral ice creams, sweets, etc.

Unit III: Floral Arrangements: Selection of containers and accessories for floral products and decorations. Flower arrangement, styles, ikebana schools (*ikenobo, ohara, sogetsu,* etc.), Ikebana- moribana, nagiere, contemporary style.

Unit IV: Dry flowers: Dry flowers– Identification and selection of flowers and plant parts; Raw material procurement, preservation and storage; tips for collecting dry flower making, selection of stages for picking of flowers for drying, Techniques in dry flower making – Drying, glycerising, bleaching, dyeing, embedding, pressing; Accessories; Designing and arrangement – dry flower baskets, bouquets, pot-pourri, wall hangings, button holes, greeting cards, wreaths; petal embedded handmade papers, Packaging and storage. Post drying management including moisture, pests and molds.

Block 2: Extraction of value added products

Unit I: Essential oils: Essential oils; Selection of species and varieties (including non-conventional species), extraction methods, Packing and storage, Aromatherapy.

Unit II: Pigments and nutraceuticals: Types of pigments, carotenoids, anthocyanins, chlorophyll, betalains; Significance of natural pigments as nutraceuticals, Extraction methods and applications in food, pharmaceutical and poultry industries.

Unit III: Dying: Synthetic and Natural dyes, dying techniques, colour retention,

VII. Practical

- Practices in preparation of different type of flower arrangements including bouquets, button-holes, flower baskets, corsages, floral wreaths, garlands with fresh flowers (4);
- Techniques in flower arrangement and floral decoration (2);
- Identification of plants for dry flower making (2);
- Practices in dry flower making; Preparation of dry flower baskets, bouquets, pot-pourri, wall hangings, button holes, greeting cards, wreaths, etc. (2);
- Essential oil extraction units (1);
- Extraction of pigments (2);
- Visit to dry flower units (2);
- Economics of value added products (1).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to

- Understand and prepare different value added products from flowers
- Develop entrepreneurial acumen
- Imbibe the skills for making various value added products

X. Suggested Reading

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.

Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants.* Vol. XII, Parts 1 & 2. pp.533 and pp.574. Malhotra Publ. House, New Delhi, India.

Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices.*Agrobios Publ., Jodhpur.

Nowak J and Rudnicki RM. 1990. *Postharvest handling and storage of cut flowers, florist greens, and potted plants*. Timber Press, USA. pp. 210.

Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publ., Jodhpur.

Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India.

I. Course Title : Protected Cultivation of Flower Crops

II. Course Code : FLS 510

III. Credit Hours : (2+1)

IV. Why this course ?

Protected cultivation is more rewarding in production of high value cut flowers. With appropriate structures and plant environment control measures, the constraints of environment prevalent in the region can be overcome allowing almost year-round cultivation. The students need a thorough understanding of principles, types, designs, crops for different environments and management of environment in protected cultivation.

V. Aim of the course

Understanding the principles, theoretical aspects and developing skills in protected cultivation of flower crops.

The course is organized as follows

No	Blocks	Units
1	Principles and types	I Prospects and types of protected structures
		II Principles and designs
2	Growing Environment	I Control of environment
		II Crop management and crop regulation
		III Automation and standards

VI. Theory

Block 1: Principles and types

Unit I: Prospects and types of protected structures: Prospects of protected floriculture in India; Types of protected structures – Glasshouse/ polyhouse, shadenet houses, mist chambers, lath houses, orchidarium, fernery, rain shelters, etc.

Unit II: Principles and design: Principles of designing and erection of protected structures; Low cost/ Medium cost/ High cost structures; Location specific designs; Structural components; Suitable flower and foliage plants for protected cultivation.

Block 2: Growing environment

Unit I: Control of environment: Microclimate management and manipulation of temperature, light, humidity, air and CO_2; Heating and cooling systems, ventilation, naturally ventilated greenhouses, fan and pad cooled greenhouses, light regulation, water harvesting.

Unit II: Intercultural operations and crop regulation: Containers and substrates, media, soil decontamination, layout of drip and fertigation system, water and nutrient management, IPM and IDM, Crop regulation by chemical methods and special horticultural practices (pinching, disbudding, deshooting, deblossoming, etc.); Staking and netting, Photoperiod regulation.

Unit III: Automation and standards: Automation in greenhouses, sensors, solar greenhouses and retractable greenhouses, GAP/ Flower labels, Export standards, EXIM policy, APEDA regulations for export, Non-tariff barriers.

Crops

Rose, Chrysanthemum, Carnation, Gerbera, Orchids, Anthuriums, Lilium, Limonium, Lisianthus, heliconia, Cala lily, Alstromeria, etc.

VII. Practical

- Study of various protected structures (1);
- Design, layout and erection of different types of structures (2);
- Practices in preparatory operations, growing media, soil decontamination techniques (2);
- Microclimate management (2);
- Practices in drip and fertigation techniques, special horticultural practices (2);
- Determination of harvest indices and harvesting methods (1);
- Postharvest handling, packing methods (1);
- Economics of cultivation, Project preparation (2);
- Project Financing guidelines (1);
- Visit to commercial greenhouses (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to be acquire

- Knowledge on types, design and principles of protected structures
- Thorough understanding of principles of microclimate management and crop management.
- Develop the required skills for designing a greenhouse
- Acquire skills on microclimate management, production management

X. Suggested Reading

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.

Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash,

Kolkata, India.
Bose TK and Yadav LP. 1989. *Commercial Flowers*. Naya Prokash, Kolkata, India.
Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants*. Vol. XII, Parts 1 & 2. pp.533 and pp.574. Malhotra Publ. House, New Delhi, India.
Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices*.Agrobios Publ., Jodhpur.
Nelson PV. 2011. *Green House Operation and Management*. Pearson Publ. 7th edition, pp. 624.
Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publ., Jodhpur.
Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.
Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India

I. Course Title : CAD for Landscaping

II. Course Code : FLS 511

III. Credit Hours : (1+2)

IV. Why this course ?

CAD is widely used in landscaping planning and design. The students need to develop in depth knowledge of CAD software so that they can modify raw data into plans, drawing and models for landscape planning.

V. Aim of the course

To impart basic knowledge about the Computer Aided Designing (CAD) of landscape.

The course is organized as follows

No	Blocks	Units
1	CAD	I CAD basics and applications II 2D drawing
2	ARCHICAD	I 3D drawing II Dimensioning and visualization

VI. Theory

Block 1: CAD

Unit II: CAD basics and applications: Principles of integrating the architecture and landscaping, Exposure to CAD (Computer Aided Designing) – Applications of CAD in landscape garden designing, 2D drawing by AUTOCAD, Creating legends for plant and non-plant components, Basics of Photoshop software in garden designing.

Unit II: 2D drawing: 2D drawing methods, AUTOCAD Basics, Coordinate systems in AUTOCAD LT 2007, Point picking methods, Toolbars and Icons, File handling functions, Modifying tools, Modifying comments, Isometric drawings, Drafting objects. Using patterns in AUTOCAD drawing, Dimension concepts, Hyperlinking, Script making, Using productivity tools, e-transmit file, making sample drawing for outdoor and indoor garden by AUTOCAD 2D Drawing techniques, Drawing web format design, Making layout.

Block 2: ARCHICAD

Unit I: 3D drawing: 3D drawing methods, 3D drawing by ARCHICAD, 3D drawing by 3D MAX software, ARCHICAD file system, Tools and Infobox, modification tools, structural elements, GDL objects (Grid Dimensional Linking), Creation of garden components through ARCHICAD.

Unit II: Dimensioning and visualization: ARCHICAD organization tools, Dimensioning and detailing of designs, Landscape designing softwares and CD ROM for ornamental plant material (TRES, HIMFLORA, CAPSSA, etc), Attribute settings of components, Visualization tools for landscape preview, Data management, plotting and accessories for designing, Inserting picture using photoshop, Making sample drawing for outdoor and indoor gardens.

VII. Practical

- Practices in point picking methods, Using tool bars and icons, Using modifying tools and modifying comments (4);
- Isometric drawings, Using productivity tools (2);
- Drawing designs by AUTOCAD for home garden, institutional garden and special types of garden (4);
- Using tools and info-box for 3D drawing, Creation of garden components with ARCHICAD (4);
- Organization, dimensioning, detailing and visualization tools with ARCHICAD (4);
- Using Photoshop package for 3D picture insertion (2);
- Drawing designs with ARCHICAD for home garden, interior garden designing, IT parks, Corporates, Theme parks and Ecotourism spots (6);
- Exposure visits (4).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to develop

- The students will be able to use CAD and ARCHICAD for landscape planning and designing.
- Develop the adequate skills to create 3 D model to showcase interaction of different factors in landscape gardening.
- Develop the entrepreneurial acumen

X. Suggested Reading

Christine, Wein-Ping Yu. 1987. *Computer-aided Design: Application to Conceptual Thinking in Landscape Architecture*. amazon.com.

Misra RL and Misra S. 2012. *Landscape Gardening*. Westville Publ. House, New Delhi, India.

I. Course Title : Seed Production in Flower Crops

II. Course Code : FLS: 512

III. Credit Hours : (1+1)

IV. Why this course ?

Seed production of flowers is a highly remunerative enterprise. The students need to have knowledge of seed industry, seed production methods and seed certification. This course provides hands on training on seed production of important flower crops.

V. Aim of the course

To impart basic knowledge about the importance of seed production in important flower crops.

The course is organized as follows

No	Blocks	Units
1	Seed Industry	I Scenario of Seed industry
2	Hybrid Seed Production	I Seed Production methods
		II Population improvement
		III F1 Hybrid production
3	Regulations	I Seed certification and standards

VI. Theory

Block 1: Seed Industry

Unit I: Scenario of Seed Industry: Scope, scenario and importance of seed production in flower crops. Constraints in flower seed production. Marketing and economics of flower seeds.

Block 2: Hybrid Seed Production

Unit I: Seed production-Methods: Methods of seed production, agrotechniques for production of nucleus, breeder and certified seeds. Harvesting, seed processing, seed priming, seed chain, packaging and storage.

Unit II: Population improvement: Mass selection, progeny selection.Use of incompatibility and male sterility, maintenance of variety and seed production in flower crops.

Unit III: F1 hybrids: F1 hybrid seed production advantages, steps involved in hybrid seed production, pollination behaviour and isolation, pollination management methods in production of F1/ hybrids in different flower crops.

Block 3: Regulations

Unit I: Seed certification and standards: Seed certification, Seed standards, seed act, plant breeders rights and farmers' rights, Bio safety, handling of transgenic seed crops, importing of seeds and OGL, trade barriers in seed business, sanitary and phytosanitaty issues, custom clearance and quarantine.

Crops

Marigold, petunia, antirrhinum, zinnia, pansy, lupin, calendula, phlox, vinca, dianthus, sunflower, annual chrysanthemum, poppy, corn flower, rice flower.

VII. Practical

- Seed production of open pollinated varieties (2);
- Seed production of cross pollinated varieties (2);
- Steps involved in hybrid seed production (2);
- Hybrid seed production in different flower crops like marigold, petunia, antirrhinum, zinnia, pansy, lupin, calendula, phlox, vinca, dianthus, sunflower, annual chrysanthemum, etc. (6);
- Visit to seed industry (3);
- Visit to quarantine facility (1).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will get a thorough knowledge on seed industry, principles and methods of seed production in flower crops.
- Students will get awareness on seed standards, certification and law in flower crops.

X. Suggested Reading

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.

Bose TK, Yadav LP, Pal P, Parthasarathy VA and Das,P. 2003. *Commercial Flowers*. Vol. I & II. Naya Udyog, Kolkata, India.

Davies, Fred T Jr., Geneve RL, Wilson SB, Hartmann HT. Kester DL. 2018. *Hartmann and Kester's Plant Propagation: Principles and Practices*. Pearson Publ.9th Edition.

Larson RA and Armitage AM. 1992. *Introduction of Floriculture*. International Book Distributing Co., Lucknow, India.

Course Title with Credit Load
Ph.D. (Hort.) in Floriculture and Lanscaping

Course Code	Course Title	Credit Hours
	Major Courses(12 Credits)	
FLS 601*	Crop Regulation in Ornamental Crops	1+1
FLS 602*	Postharvest Biology of Floricultural Crops	2+1
FLS 603	Specialty Flowers, Fillers and Cut Greens	1+1
FLS 604	Biotechnological Approaches in Floricultural Crops	2+1
FLS 605*	Advances in Landscaping	1+1
FLS 606	Vertical Gardening	1+2
FLS 607	Modern Approaches in Breeding of Floricultural crops	2+1
FLS 608	Current Trends in Production Technology of Floricultural Crops	2+1
FLS 609	Recent Developments in Protected Cultivation of Floricultural Crops	2+1
	Minor courses	06
	Supporting courses	05
FLS 691	Seminar-I	0+1
FLS 692	Seminar-II	0+1
FLS 699	Research*	0+75
	Total Credits	**100**

*Compulsory among major courses

Course Contents
Ph.D. (Hort.) in Floriculture and Lanscaping

I. Course Title : Crop Regulation in Ornamental Crops
II. Course Code : FLS 601
III. Credit Hours : (2+1)

IV. Why this course ?

The course deals with the physiological and biochemical basis of crop regulation and programmed production of flower crops. The students need a thorough understanding on crop regulation to improve the profitability of growers.

V. Aim of the course

Appraise on advances in programmed production of flower crops

The course is organized as follows:

No	Blocks	Units
1	Basis of crop regulation	I Basis of flowering II Growth regulators
2	Programming	I Growth regulation II Programmed production

VI. Theory

Block 1: Basis of crop regulation

Unit I: Basis of flowering: Ecophysiological influences on growth and development of flower crops for flowering, Crop load and assimilate partitioning and distribution.Root and canopy regulation.

Unit II: Growth regulators: Study of plant growth regulators including biostimulants and polyamines in floriculture- structure, biosynthesis, metabolic and morphogenetic effects of different plant growth promoters and growth retardants. Absorption, translocation and degradation of phytohormones – internal and external factors influencing hormonal synthesis, biochemical action, growth promotion and inhibition, Plant architecture management for flower crops and ornamental plants, molecular approaches in crop growth regulation.

Block 2: Programming

Unit I: Growth regulation: Growth regulation aspects of propagation, embryogenesis, seed and bud dormancy, flower bud initiation, regulation of flowering, photo and thermo periodism, off season production, bulb forcing techniques.

Unit II: Programmed production: Programmed production of important flower crops like chrysanthemum, tulips, lilium, daffodils, poinsettia, kalanchoe, gypsophila.

VII. Practical

- Plant architecture studies in important flower crops (2);
- Bioassay and isolation through chromatographic analysis for auxins, gibberellins, cytokinins, ABA (4);
- Growth regulation during propagation, dormancy, flowering (2);
- Photoperiod regulation in short day and long day crops (2);
- Off season production in important crops (2);
- Bulb forcing in bulbous ornamental crops (2);
- Exposure visits (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will be abreast with physiological and biochemical basis of crop regulation in flower crops.
- The students will be able to carry out programmed production of flower crops.
- Instill the entrepreneurial acumen in the students

X. Suggested Reading

Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. 2015. Wiley Blackwell Publ. 2nd Edition, pp. 1280.

De Hertagh A and Le Nard M. 1993. *The Physiology of Flower Bulbs*. Elsevier, London, UK.

Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*. John Wiley & Sons.

Fosket DE. 1994. *Plant Growth and Development: A Molecular Approach*. Academic Press. pp. 580.

Leoplod AC and Kriedermann PE. 1985. *Plant Growth and Development*. McGraw-Hill, New York. 3rd Edition.

Peter KV. 2008. *Basics of Horticulture*. New India Publ. Agency, New Delhi, India.

Roberts J, Downs S and Parker P. 2002. *Plant Growth Development*: *In Plant*. Oxford University Press. pp. 221-274.

Salisbury FB. and Ross CW. 1992. *Plant Physiology, Hormones and Plant Regulators: Auxins and Gibberellins*. Wadsworth Publ., Belmont. 4th Edition, pp. 357-381.

I. Course Title : Postharvest Biology of Floricultural Crops

II. Course Code : FLS 602

III. Credit Hours : (2+1)

IV. Why this course ?

The course deals with physiological, biochemical basis of senescence of flowers and the treatments and packaging methods to mitigate these processes for improving post-harvest life.

V. Aim of the course

To facilitate deeper understanding of biochemistry and postharvest technology in flowers at molecular as well as applied level.

The course is organized as follows:

No	Blocks	Units
1	Pre-harvest and post harvest physiology and biochemistry	I Pre harvest physiology II Senescence III Pigments and secondary metabolites
2	Storage and packaging	I Treatments and storage II Packaging III Dried ornamental crops

VI. Theory

Block 1: Preharvest and post harvest physiology and biochemistry

Unit I: Pre harvest physiology: Maturity indices, harvesting practices for specific market requirements, influence of pre-harvest practices, enzymatic and other biochemical changes, respiration, transpiration in important flower crops.

Unit II: Senescence: Physiology and biochemistry of flowering, enzymatic changes, Ethylene sensitivity, ethylene evolution and management, factors leading to post-harvest loss, pre-cooling. Petal senescence at molecular level, functional gene analysis for postharvest flower quality in important flower crops, etc.

Unit III: Pigments and secondary metabolites: Biosynthetic pathways of chlorophyll, xanthophyll, carotenoids, flavonoids and anthocyanins and betalains. Chemistry and importance of secondary metabolites. Biochemistry and utilization for commercial products in important flower crops.

Block 2: Storage and packaging

Unit I: Storage of flowers: Treatments prior to shipment, viz., precooling, pulsing, impregnation, chemicals, Irradiation, biocontrol agents and natural plant products. Methods of storage: ventilated, refrigerated, Modified atmosphere, Controlled atmosphere storage, cool chain management, physical injuries and disorders in important flower crops.

Unit II: Packaging: Packing methods and transport, Smart technologies in packaging and storage, advanced tools like nanotechnology application for quality parameters and post harvest treatments for export in important flower crops, packaging standards, flower labels value chain in floriculture.

Unit III: Recent trends: Recent trends- extraction of bio-colours from flowers-conventional as well as *in-vitro* methods and their value addition uses in food and textile industries. Molecular techniques for enhancing postharvest flower quality, transgenics in ornamental plants for enhanced postharvest life.

Unit IV: Dried ornamental crops: Post harvest handling of dried ornamental crops including packing, storage and shipment. Storage pest and mould problems in dried ornamental produce, colour retention, physiological and biochemical changes, etc.

VII. Practical

- Improved packaging and storage of important flowers (2);
- Physiological loss in weight of flowers, estimation of transpiration, respiration rate, ethylene release and study of vase life (2);
- Extension in cut flower vase life using chemicals (1);
- Estimation of quality characteristics in stored flowers (1);
- Estimation of biochemical changes like enzymatic changes, lipids and electrolyte leakage (2);
- Extraction of flower pigments – Chlorophyll, xanthophylls, carotenoids and anthocyanins (4);
- Cold chain management – visit to cold storage, MA and CA storage units (2);
- Project preparation (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will be abreast with physiological and biochemical basis of senescence in flower crops.
- The students would acquire the required skill sets of managing the storage and packaging methods to be followed in case of flowers.
- Prepare the students to explore the entrepreneurial options in post harvest management.

X. Suggested Reading

Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. 2015. Wiley Blackwell Publ. 2nd edition, pp. 1280.

Dey PM and Harborne JB. 1997. *Plant Biochemistry*. Academic Press. 2nd Edition.

Glover MD. 1984. *Gene Cloning: The Mechanics of DNA Manipulation*. Chapman & Hall Publ.

Goodwin TW and Mercer EI. 2003. *Introduction to Plant Biochemistry*. CBS Publ.

I. Course Title : Specialty Flowers, Fillers and Cut Greens

II. Course Code : FLS 603

III. Credit Hours : (1+1)

IV. Why this course ?

This course deals with introduction to specialty flowers, cut greens and fillers, ways to cultivate them and their post harvest handling and storage. The students need to be aware of these crops so that they could improve the profitability of growers.

V. Aim of the course

To impart the knowledge on importance and cultivation of specialty flowers, fillers and cut green crops.

The course is organized as follows:

No	Blocks	Units
1	Scope	I Importance, national and international scenario
2	Avenues	I Specialty flowers II Fillers III Cut greens
3	Trade and marketing	I Post harvest management and marketing 2. Standards

VI. Theory

Block 1: Scope

Unit I: Importance, national and international scenario: Introduction, present status, scope, importance and avenues for specialty flowers and cut greens.

Block 2: Avenues

Unit I: Specialty flowers: Cultivation practices of specialty flower crops like heliconia, red ginger, Bird of Paradise, Ornamental banana, ornamental curcuma, gingers, wax flower, kangaroo paw, limonium, rice flower, etc.

Unit II: Fillers: Cultivation practices of fillers like gypsophila, solidago, Mollucella, lupins, etc.

Unit III: Cut greens: Cultivation practices of cut greens like anthurium, ferns, asparagus, cycas, thuja, bottle brush, ornamental palms, zanado, dracaena, eucalyptus, ruscus, dianella, alpinia, etc.

Block 3: Trade and Marketing

Unit I: Post harvest management: Pre and post harvest factors influencing the vase life of the flowers and fillers, Post harvest management including pulsing, holding, packing, storing, forward and backward linkages, value chain management.

Unit II: Standards: Quality standards, Packaging standards, marketing and trade in important flower, filler and foliage crops.

VII. Practical

- Identification of specialty flowers, fillers and cut greens (2);
- Media and bed preparation for cultivation (2);
- Propagation of important crops (2);
- Integrated disease and pest management in important crops (2);
- Post harvest handling of specialty flowers, fillers and cut greens (2);
- Preparation of value added products from important specialty flowers, fillers and foliages (2);
- Exposure visits (2);
- Economics and Project preparation (2).

VIII. Teaching Methods/ Activities

- Lectures

- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will gain knowledge on different specialty flowers, cut greens, fillers their cultivation practices and post harvest management.
- Infuse confidence to take up cultivation as an enterprise.

X. Suggested Reading

Armitage AM and Laushman JM. 2008. *Speciality Cut Flowers*. Timber Press. 2nd Edition, pp. 636.

Bhattacharjee SK. 2006. *Vistas in Floriculture*. Pointer Publ., Jaipur, India.

Bhattacharjee SK and De LC. 2003. *Advanced Commercial Floriculture* Vol.1. Aavishkar Publ. & Distributors, Jaipur India.

Bose TK, Yadav LP, Pal P, Parthasarathy VA and Das P. 2003. *Commercial Flowers*. Vol. I & II. Naya Udyog, Kolkata, India.

Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Traditional and Loose Flowers*. Kruger Brentt Publisher UK Ltd.

Mukherjee D. 2008. *Speciality Cut Flowers-Production Technologies*. Naya Udyog Kolkata, India. pp. 614.

Salunkhe K, Bhatt NR and Desai BB. 2004. *Post harvest Biotechnology of Flowers and Ornamental Plants*. Naya Prokash, Kolkata, India.

I. Course Title : Biotechnological Approaches in Floricultural Crops

II. Course Code : FLS 604

III. Credit Hours : (2+1)

IV. Why this course ?

This course deals with advances in biotechnology of flower crops. The student needs to be abreast with recent advances in tissue culture, genetic engineering and molecular biology of flower crops

V. Aim of the course

Equip the students with the advances in application of biotechnology in flower crops.

No	Blocks	Units
1	Scope of biotechnology	I Scope of biotechnology
2	Cell, Tissue and Organ culture	I Tissue cultures
		II Somaclonal variation and *in-vitro* conservation
3	Genetic engineering and molecular biology	I Genetic Engineering
		II Molecular approaches

VI. Theory

Block 1: Scope of biotechnology

Unit I: Scope of biotechnology: Present status of biotechnology, tools techniques and role in floriculture industry, physical factors and chemical factors influencing the growth and development of plant cell, tissue and organs, cyto-differentiation, organogenesis, somatic embryogenesis in important flower crops.

Block 2: Cell, tissue and organ culture

Unit I: Micropropagation: *In-vitro* lines for biotic and abiotic stress – Meristem culture for disease elimination, production of haploids through anther and pollen culture – embryo and ovule culture, micrografting, wide hybridization and embryo rescue techniques, construction of somatic hybrids and cybrids, regeneration and characterization of hybrids and cybrids, *in-vitro* pollination and fertilization, hardening media, techniques and establishment of tissue culture plants in the primary and secondary nursery in important flower crops.

Unit II: Somaclonal variation and *in-vitro* conservation: Somoclonal variation and its applications – variability induction through *in-vitro* mutation, development of cell suspension cultures, types and techniques, Synthetic Seed technology, *in-vitro* production of secondary metabolites, role of bioreactors in production of secondary metabolites, quantification and quality analysis of secondary metabolites using HPLC/ MS/ GCMS/ *in-vitro* conservation and cryo-preservation techniques in important flower crops.

Block 3: Genetic engineering and molecular biology

Unit I: Genetic engineering: Gene cloning, genetic engineering: vectors and methods of transformation – electroporation, particle bombardment, Functional gene analysis techniques like PTGS including VIGS in ornamental plants, Agrobacterium mediated, transgenic plants in flower crops, Biosafety of transgenics isolation of DNA, RNA, quantification, Polymerase Chain Reaction for amplification; AGE and PAGE techniques; identification of molecular markers in important flower crops.

Unit II: Molecular approaches: Molecular markers as a tool for analysis of genetic relatedness and selection in ornamental crops. Molecular control of flower development, light sensing with respect to plant development, flower pigmentation, fragrance, senescence, ethylene synthesis pathway in important flower crops. Molecular biology- Gene isolation, characterization, manipulation and transfer in important flower crops.

Construction of c- DNA library, DNA fingerprinting technique in economic flower crop varieties, RNAi, Genome editing basics, molecular approaches to control ethylene response, Fragrance, Plant Architecture, desirable flower traits, colour, shape, improving postharvest life, improving resistance for environmental stress, approaches to improve flower development, pigment production, secondary metabolite production, post harvest biotechnology of flowers, ornamental plants, achievements of bio-technology in flower crops.

VII. Practical

- Micropropagation, Pollen- Ovule and Embryo culture- Synthetic seed production (2);

- *In-vitro* mutation induction, *in-vitro* rooting – hardening at primary and secondary nurseries (3);
- DNA isolation from economic flower crop varieties – Quantification and amplification (2) DNA and Protein profiling – molecular markers, PCR Handling (2);
- Vectors for cloning and particle bombardment (3);
- DNA fingerprinting of flower crop varieties (3);
- Project preparation for establishment of low, medium and high cost tissue culture laboratories (1).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Suggested Reading

Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology-Concepts, Methods and Applications*. Oxford & IBH Publ. Company, USA. pp. 200.

Debnath M. 2011. *Tools and Techniques of Biotechnology*. Pointer Publ.

Glover MD. 1984. *Gene Cloning: The Mechanics of DNA Manipulation*. Chapman & Hall Publ.

Gorden H and Rubsell S. 1960. *Hormones and Cell Culture*. AB Book Publ.

Keshavachandran R, Nazeem PA, Girija D, John PS and Peter KV. 2007. *Recent Trends in Horticultural Biotechnology*. Vols. I & II, 1018 p. New India Publ. Agency, New Delhi, India.

Keshavachandran R and Peter KV. 2008. *Plant Biotechnology: Methods in Tissue Culture and Gene Transfer*. Orient Blackswan. 312 p.

I. Course Title : Vertical Gardening

II. Course Code : FLS 605

III. Credit Hours : (1+2)

IV. Why this course ?

This course deals with development in vertical gardening which is expanding across the country. In view of the unprecedented pollution, advent of smart cities demand for green walls/ living walls is increasing day by day. The students therefore need to be equipped with the advancements taking place to offer solutions.

V. Aim of the course

Equip the students with the latest developments in vertical gardening.

No	Blocks	Units
1	Importance	I Scope II Growth III Making of vertical garden
2	Green roofing	I Green facades II Mitigation of pollution III Maintenance

VI. Theory

Block 1: Importance

Unit I: Scope: Present status of vertical gardening, benefits of vertical gardening, History of vertical gardens, role of indoor plants in mitigating pollution.

Unit II: Growth: Factors influencing the growth and development of the plants including light, humidity, temperature, nutrition, irrigation, growth regulation.

Unit III: Making of vertical gardens: Containers, media, frames, cost effective components, cables, wires, nets for the vertical formations, modular living walls.

Block 2: Green roofing

Unit I: Green Facades: Influence of green facades in providing thermal comfort, atmospheric cleansing and related environmental benefits, Energy saving potential of green façades, Aesthetic appeal of green structures and other relevant studies on urban greening.

Unit II: Mitigation of pollution: Plants suitable, Dust mitigation, Radiation absorption, Pollution mitigation, Acoustic attributes of urban greening.

Unit III: Maintenance: Lifecycle, maintenance, Plants with low light, medium, high intensity requirement, cost effectiveness and overall sustainability of living walls.

VII. Practical

- Identification of plants (2);
- Components of vertical gardens (2);
- Designing of vertical gardens for different locations (4);
- Maintenance of vertical gardens (2);
- Economics (1);
- Project preparation (1);
- Exposure visit (4).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Suggested Reading

Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology-Concepts, Methods and Applications*. Oxford & IBH Publ. Company, USA. pp. 200.

Debnath M. 2011. *Tools and Techniques of Biotechnology*. Pointer Publ.

Glover MD. 1984. *Gene Cloning: The Mechanics of DNA Manipulation*. Chapman & Hall Publ.

Gorden H and Rubsell S. 1960. *Hormones and Cell Culture*. AB Book Publ.

Keshavachandran R, Nazeem PA, Girija D, John PS and Peter KV. 2007. *Recent Trends in Horticultural Biotechnology*. Vols. I & II, pp. 1018. New India Publ. Agency, New Delhi, India.

Keshavachandran R and Peter KV. 2008. *Plant Biotechnology: Methods in Tissue Culture and Gene Transfer*. Orient Blackswan. pp. 312.

I. Course Title : Advances in Breeding of Flower Crops

II. Course Code : FLS 606

III. Credit Hours : (2+1)

IV. Why this course ?

There have been several advances in application of biotechnology of flower crops. The students need to be aware of a wide array of *in-vitro* and molecular techniques with reference to flower crops.

V. Aim of the course

To teach students about the recent research trends in the field of breeding of ornamental crops with special emphasis on biotechnological approaches.

The course is organized as follows:

No	Blocks	Units
1	*In-vitro* techniques and biosynthetic pathways	I *In-vitro* techniques II Biosynthetic pathways
2	Molecular techniques	I Molecular breeding II Genome editing III. Advances in flower crops

VI. Theory

Block 1: *In-vitro* techniques and biosynthetic pathways

Unit I: *In-vitro* techniques: Role of biotechnology in improvement of flower crops; *in-vitro* mutagenesis, embryo culture, somaclonal variation, transformation, *in-vitro* cryopreservation, somatic hybridization, anther and ovule culture including somatic embryogenesis.

Unit II: Biosynthetic pathways: Biosynthetic pathways of pigment, fragrance and senescence, flower form; chemistry and importance of secondary metabolites, genomics, proteomics, metabolomics.

Block 2: Molecular techniques

Unit I: Molecular breeding: Molecular breeding and Marker assisted selection; molecular characterization; construction of c-DNA library; High throughput sequencing.

Unit II: Genome editing: Genome editing, CRISPER CAS, gene pyramiding, allele mining.

Unit III: Advances in flower crops: Breeding for biotic and abiotic stresses using biotechnological means; designer flower crops. Advancements in important flower crops like rose, chrysanthemum, carnation, orchids, anthuriums, lilium, gerbera, etc.

VII. Practical

- *In-vitro* mutagenesis, embryo culture, somaclonal variation (2);
- Somatic hybridization, anther and ovule culture and somatic embryogenesis (2)

- Genetic transformation (2);
- Genetic fingerprinting, Genome editing techniques (4);
- PCR, genomics, blotting techniques (2);
- Cloning, marker assisted selection (2);
- Bioinformatics (2).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will have in depth knowledge and hands on training in *in-vitro* and molecular approaches that can be used in flower crops.
- Equip the students with the skills for develop designer crops

X. Suggested Reading

Anderson NO. 2007. *Flower Breeding and Genetics Issues, Challenges and Opportunities for the 21st Century*. Springer Publ., The Netherlands.

Arthur ML. 2013. *Introduction to Bioinformatics*. Oxford University Press, U.K. 400 p.

Chadha KL and Chaudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.

Nelson DL and Cox MM. 2000. *Principles of Biochemistry*. 4th Edition, Lehninger Publ.

Panopoulas NJ (Ed.). 1981. *Genetic Engineering in Plant Sciences*. Praeger Publ.

Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK and Mohanadas S. 2001. *Biotechnology of Horticultural Crops*. Vol. I-III. Naya Prokash, Kolkata, India.

Pierik RLM. 1987. *In-vitro Culture of Higher Plants*. MartinusNijhoff Publ. Amsterdam.

Primrose SB and Twyman R. 2006. *Principles of Gene manipulation and Genomics*. Blackwell Publ., USA.

Srivastava PS, Narula A and Srivastava S. 2005. *Plant Biotechnology and Molecular Markers*. Anamaya Publ., New Delhi, India.

Vainstein A. (Ed.) 2002. *Breeding for Ornamental crops: Classical and Molecular Approaches*. Springer-Science-Business Media, B.V. 1st Edition.

Wilson K and Walker J. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*. 7th Edition, Cambridge University Press, UK.

I. Course Title : Advances in Production Technology of Flower Crops

II. Course Code : FLS 607

III. Credit Hours : (2+1)

IV. Why this course ?

Production technology of flower crops is undergoing a rapid change due to advances from other sciences. The students need to keep abreast with these advances in production technology in flower crops.

V. Aim of the course

To keep abreast with latest developments and trends in production technology of flower crops.

The course is organized as follows:

No	Blocks	Units
1	Production technology	I Scope and scenario II Cultural operations III Crop regulation IV Advances in production technology of flowers
2	Mechanization and Post harvest management	I Mechanization II Post harvest management

VI. Theory

Block 1: Production technology

Unit I: Scope and scenario: Commercial flower production; Scope and importance; Global Scenario in cut flower production and trade, varietal wealth and diversity; Soil and Environment; cut flower, loose flowers, dry flowers and essential oil trade, flower seed production. Special characteristics and requirements. Essential oil industry, recent advances in extraction methods.

Unit II: Cultural operations: Propagation and multiplication; Greenhouse management; Soil/ media decontamination techniques; Microirrigation; nutrition and fertigation; slow release fertilizers and biofertilizers; influence of environmental parameters, light, temperature, moisture, humidity and CO_2 on growth and flowering.

Unit III: Crop Regulation: Flower forcing and year-round flowering through physiological interventions; Chemical regulation; Environmental manipulation, important insect pests, diseases, nematodes and their management through IPM and IDM, quarantine measures for export and other export norms.

Unit IV: Advances in production technology of crops: Advances in roses, chrysanthemum, carnation, tuberose, gladiolus, lilum, gerbera, orchids, anthuriums, etc.

Block 2: Mechanization and Post harvest management

Unit I: Mechanization: Mechanization, automation, ICT and AI in floriculture.

Unit II: Post-harvest management: Harvest indices, Harvesting techniques; Post harvest handling for local, distant and export market, Cluster production, Contract farming, FPOs, Value chain management.

VII. Practical

- Greenhouse management; Soil decontamination techniques (2);
- Microirrigation; Nutrition and fertigation (2);
- Special practices- bending, netting, pinching, disbudding, defoliation and chemical pruning, etc. (2);
- Photoperiodic and chemical induction of flowering (2);
- Assessing harvest indices; Post-harvest handling (2);
- Case studies (2);
- Visit to commercial cut flower and essential oil units (4).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will acquire knowledge and skills in advances in production technology, crop regulation and mechanization in flower crops.
- Develop enterprising attitude among students.

X. Suggested Reading

Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.

Chadha KL and Choudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.

George S and Peter KV. 2008. *Plants in a Garden*. New India Publ. Agency, New Delhi, India.

Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices*.Agrobios Publ., Jodhpur, India.

Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Traditional and Loose Flowers*. Kruger Brentt Publisher UK Ltd.

Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.

Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi India.

Singh AK. 2006. *Flower Crops: Cultivation and Management*. New India Publ. Agency, New Delhi, India.

Singh AK. 2014. *Breeding and Biotechnology of Flowers, Vol.1: Commercial Flowers*. New India Publ. Agency, New Delhi, India. pp.740.

I. Course Title : Advances in Protected Cultivation of Flower Crops

II. Course Code : FLS 608

III. Credit Hours : (2+1)

IV. Why this course ?

Protected cultivation is more rewarding in production of high value cut flowers. With appropriate structures and plant environment control measures, the constraints of environment prevalent in the region can be overcome allowing almost year-round cultivation. The students need to get updated with the recent advances in protected cultivation.

V. Aim of the course

Appraisal on the advances in protected and precision farming of flower crops.

The course is organized as follows:

No	Blocks	Units
1	Production technology	I Scope and Scenario II Microclimate management III Cultural operations

No	Blocks	Units
		IV Advances in flower crops
2	Precision floriculture and regulations	I Precision floriculture II Regulations

VI. Theory

Block 1: Production technology

Unit I: Scope and Scenario: Prospects of protected floriculture in India, growing structures, basic considerations in establishment and operation of green houses, functioning and maintenance. Global trade, forward and backward linkages for import clusters, International and national auction houses.

UNIT II: Microclimate management: Environmental control systems in greenhouse, regulation of light through LEDs containers, substrate culture, soil decontamination techniques, aeroponics, hydroponics and vertical farming.

Unit III: Cultural operations: Water and nutrient management, crop regulation, special horticultural practices under protected cultivation of rose, chrysanthemum, carnation, orchids, anthurium, gerbera, lilium, cut foliage and potted ornamental crops; plant architecture management in ornamental plants.

Unit IV: Advances in flower crops: Advances in protected cultivation of important flowering (rose, chrysanthemum,carnation, gerbera, orchids, anthurium, lilium, and foliage plants (agloenema, monstera, dracaena, syngonium, pothos, diffenbachia, etc.)

Block 2: Precision floriculture and regulations

Unit I: Precision floriculture: Precision floriculture, Principles and concepts, enabling technologies of precision floriculture, remote sensing, sensors, automation in greenhouses, solar greenhouses, retractable greenhouses. Computers and robotics, decision support systems, apps, cold chain management, use of AI for production and trade.

Unit II: Regulations: PBR/ IPR issues; Forward and backward linkages, 100% EOU, packaging and export standards, Cool chain Management, non-tariff barriers, APEDA regulations for export, marketing channels, auction houses, major markets.

VII. Practical

- Growing structures, basic considerations in establishment and operation of greenhouses;
- Environmental control systems in greenhouse;
- Containers, substrate culture, soil decontamination techniques;
- Crop regulation;
- Special horticultural practices under protected cultivation;
- Precision equipments, computers and robotics in precision farming;
- Harvest indices – harvesting, Post harvest handling, marketing;
- Export and cold chain management.

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will be abreast with the recent advances in protected cultivation of flower crops
- Equip the students with skill to independently manage enterprises

X. Suggested Reading

Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, 2065 p.

Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.

Reddy S, Janakiram T, Balaji, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India.

I. Course Title : Advances in Landscape Gardening

II. Course Code : FLS 609

III. Credit Hours : (1+2)

IV. Why this course ?

Advances in landscape gardening is a course which deals with principles of landscape design, landscape engineering and site analysis. It will also create awareness on latest developments in landscape gardening among students.

V. Aim of the course

To update knowledge on the recent trends in the field of landscape designing and developing practical skills.

The course is organized as follows:

1. Landscape design
2. Site analysis
3. Software in landscaping
4. Landscaping for different situations
5. Maintenance

VI. Theory

Unit I

Landscape design: Commercial landscape gardening- History, Plant identification and ecology, Materials of garden design, Design making by different garden styles and types. Design principles in ancient and modern landscape. Principles of designing a commercial landscape project. Role of landscaping in environment improvement, ecology conservation (birds, butterflies, animals). Plant wealth for edges, hedges, herbaceous borders, trees, floral beds, water plants, cacti, ferns, palms, etc.

Unit II

Site analysis: Assessing site and plants adaptability for different locations, Landscape engineering (Topographical survey and designing concept including GIS,GPS, Remote sensing), special techniques in garden landscaping (Burlapping, waterscaping, xeriscaping, hardscaping, lawn establishment, topiary styles specializing, bioaesthetic planning).

Unit III

Software in landscaping: Preparation and drawing of site plan, Learning the basics in computer aided design (CAD) for developing a garden landscape plan, Handling soft landscape materials (AUTOCAD and ARCHICAD), GIS as a tool for spatial designing.

Unit IV

Landscaping for different situations: Contemporary landscaping, Urban landscaping, Environmental landscaping, Industrial and institutional landscaping, Public and private garden making, play ground landscaping, Inventory management, Landscape restoration, Assessing a successful design in site.

Unit V

Maintenance: Maintenance of different types of gardens, waste water utilisation, historical and archaeological garden sites, Permissions required for bigger projects, carbon sequestration, carbon credits etc.

VII. Practical

- Plant identification (1);
- Materials of garden design, Design making by different garden styles and types (2);
- Assessing site and plants adaptability for different locations (2);
- Way of designing a commercial landscape project (4);
- Landscape engineering (Topographical survey and designing concept) (2);
- Preparation and drawing of site plan (4);
- Learning the basics in computer aided design (CAD) for developing a garden landscape plan (4);
- Handling soft landscape materials (AUTOCAD and ARCHICAD), GIS as a tool for spatial designing (4);
- Case study with the successful landscapist (4);
- Budget/ Project cost estimating (2);
- Exposure visits (3).

VIII. Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

IX. Learning outcome

After successful completion of this course,

- The students will be abreast with the recent advances in landscape gardening
- Acquire the skills to independently handle landscape projects

X. Suggested Reading

Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.

Nambisan KMP.1992. *Design Elements of Landscape Gardening*. Oxford & IBH Publ. Co., New Delhi, India.

Ozayuvuz M. 2013. *Advances in Landscape Architecture*. In Tech Open Publ.

Woodrow MG. 1999. *Gardening in India*. Biotech Books, New Delhi, India.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Horticultural Sciences
– Plantation, Spices, Medicinal and Aromatic Crops

Preamble

(Plantation, Spices, Medicinal and Aromatic Crops)

Plantation Crops are high value commercial crops of greater economic importance and play a vital role in our national economy. Crops like tea, coffee, rubber, coconut, arecanut, cocoa, oil palm, cashew, etc. occupy less than two percent of the total cultivated area but have a stake of 16% of the total export earnings of all commodities or 75% of total earnings from the export of agricultural produce. Plantation industry provides direct as well as indirect employment to many millions of people and also supports other by-product industries and many rural industries. Therefore, the country has considered horticulture and plantation sector as the growth engine of agricultural economy.

Spices are important group of horticultural crops providing livelihood to millions of peoples in the country. They have tremendous importance in the way we live, as ingredients in foods, alcoholic beverages, medicine, perfumery, cosmetics, pharmaceuticals, coloring and also as garden plants. Out of the total 109 spices listed by the International Organization for Standards (ISO), 63 are grown in India. The trade in spices is one of the oldest and currently the most important form of commerce. The tropical humid regions of India grows major spices like black pepper, cardamom, ginger, turmeric, nutmeg, cinnamon, clove, etc. and the arid and semi arid parts of India are known as the seed spice bowl.

The medicinal and aromatic plant sector plays a significant role in the subsistence economy of the people. The domestic as well as export market of MAP is ever increasing. The annual turn over of the major Indian systems of medicine ie, Ayurveda, Unani, and Sidha is estimated to be more than half a million dollars. The MAP sector is also an integral part of natural resource management contributing to economic growth, environmental protection and trade.

In the present syllabus, courses have been organized to cover the current requirements of the plantation, spice and MAP sector to increase the capability of horticulture graduates. Either new courses have been formulated or existing courses upgraded to include latest developments in various sectors. In the masters programme new courses ie, systematics, growth and development, biochemistry and biodiversity conservation of PSMA crops have been included. In most of the PSMA crops quality of the produce is of paramount importance and hence a thorough understanding of the systematics, growth and developmental physiology and biochemistry is essential. To ensure sustainability aspects, biodiversity management are also added. Both national as well as global perspectives are taken care of in deciding the course content, especially in the case of doctoral programme. Tools of biotechnology have been extensively utilized in the improvement of PSMA crops and the course to this effect has been included. As the climate changes are happening globally and being crops which are greatly influenced by the change if climate, a course on abiotic stress management is included. As most of the PSMA crops are export oriented, separate courses on organic production and export are also included. All courses are designed in line with the national initiatives as well as the global scenario.

Course Title with Credit Load M.Sc. (Hort.) in Plantation, Spices, Medicinal and Aromatic Crops

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
PSM 501*	Production of Plantation Crops	2+1
PSM 502*	Production of Spice Crops	2+1
PSM 503*	Production of Medicinal and Aromatic Crops	2+1
PSM 504*	Breeding of Plantation and Spice Crops	2+1
PSM 505*	Breeding of Medicinal and Aromatic Crops	1+1
PSM 506	Systematics of Plantation and Spice Crops	1+1
PSM 507	Systematics of Medicinal and Aromatic Crops	1+1
PSM 508	Underexploited Plantation, Spice, Medicinal and Aromatic Plants	2+0
PSM 509	Growth and Development of Plantation, Spice, Medicinal and Aromatic Crops	2+1
PSMA 510	Biochemistry of Plantation, Spice, Medicinal and Aromatic crops	2+1
PSMA 511	Biodiversity and Conservation of Plantation, Spice, Medicinal and Aromatic Crops	2+1
	Minor Courses	08
	Supporting Courses	06
	Common compulsory courses	05
PSMA 591	Seminar	0+1
PSMA 599	Research	0+30
	Total	**70**

*Compulsory among major courses

Course Contents
M.Sc. (Hort.) in Plantation, Spices, Medicinal and Aromatic Crops

I. Course Title : Production of Plantation Crops

II. Course Code : PSM 501

III. Credit Hours : (2+1)

IV. Why this course ?

Plantation crops play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers. This course will impart theoretical as well as hands-on experience to the learner on scientific production technology of various plantation crops in Indian perspectives. It will provide comprehensive knowledge in this regard.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on various aspects of production technology of plantation crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Plantation Crops	I Role of plantation crops II Export potential III Promotional programmes
2	Production Technology	I Varietal wealth II Propagation and nursery management III Agro techniques
3	Harvest and Post-harvest management	I Maturity indices and harvest II Post harvest management

VI. Theory

Block 1: Importance of Plantation Crops

Unit 1: Role of plantation crops: Role of plantation crops in national economy, area-production statistics at national and international level, classification, clean development mechanism and carbon sequestration potential of plantation crops.

Unit 2: Export potential: Export potential, problems and prospects and IPR issues in plantation crops.

Unit 3: Promotional programmes: Role of commodity boards and directorates in the development programmes of plantation crops.

Block 2: Production Technology

Unit 1: Varietal wealth: Botany, taxonomy, species, cultivars and improved varieties in plantation crops.

Unit 2: Propagation and nursery management: Plant multiplication including *in-vitro* multiplication, nursery techniques and nursery management in plantation crops.

Unit 3: Agro techniques: Systems of cultivation, cropping systems, multitier cropping, climate and soil requirements, systems of planting, high density planting, nutritional requirements, water requirements, fertigation, moisture conservation, role of growth regulators, macro and micro nutrients, nutrient deficiency symptoms, physiological disorders, shade regulation, weed management, training and pruning, crop regulation, plant protection, management of drought, precision farming.

Block 3: Harvest and Post harvest management

Unit 1: Maturity indices and harvest: Maturity indices, harvesting methods, harvesting seasons and mechanized harvesting in plantation crops.

Unit 2: Post harvest management: Post harvest handling including primary processing, grading, packaging, storage and benefit cost analysis of plantation crops.

Crops

Coconut, Arecanut, Oilpalm, Cashew, Coffee, Tea, Cocoa, Rubber, Palmyrah, Betel vine

VII. Practical

- Description of botanical and varietal features;
- Selection of mother palms and seedlings;
- Nursery techniques;
- Soil and water conservation measures;
- Nutrient deficiency symptoms;
- Manuring practices;
- Pruning and training methods;
- Maturity standards;
- Harvesting;
- Project preparation for establishing plantations;
- GAP in plantation crops;
- Exposure visits to commercial plantations, research institutes.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Develop the technical skill in commercial cultivation of plantation crops
- Be able to start plantation crop-based enterprises

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.
Anonymous. 1985. *Rubber and its Cultivation*. The Rubber Board of India.
Chopra VL and Peter KV. 2005. *Handbook of Industrial Crops*. Panima.
Choudappa P, Anitha K, Rajesh MK and Ramesh SV. 2017. *Biotechnology of Plantation Crops*.

Daya Publishing House, New Delhi
Choudappa P, Niral V, Jerard BA and Samsudeen K. 2017. *Coconut*. Daya Publishing House, New Delhi.
e-manual on Advances in Cashew Production Technology. ICAR –Directorate of Cashew Research, Puttur –574 202, DK, Karnataka.
Harler CR. 1963. *The Culture and Marketing of Tea*. Oxford Univ. Press.
Joshi P. 2018. *Text Book on fruit and plantation crops*. Narendra Publishing House, New Delhi
Kurian A and Peter KV. 2007. *Commercial Crops Technology*. New India Publ. Agency.
Nair MK, Bhaskara Rao EVV, Nambia KKN and Nambiar MC. 1979. *Cashew*. CPCRI, Kasaragod.
Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.
Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.
Peter KV. 2002. *Plantation Crops*. National Book Trust.
Pillay PNR. 1980. *Handbook of natural rbber production in India*. Rubber Research Institute, Kottayam. pp.668.
Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2007. *Management of Horticultural Crops*. Parts I, II. New India Publ. Agency.
Ramachandra *et al*. 2018. *Breeding of Spices and Plantation crops*. Narendra Publishing House, New Delhi.
Ranganathan V. 1979. *Hand Book of Tea Cultivation*. UPASI, Tea Res. Stn. Cinchona.
Sera T, Soccol CR, Pandey A, Roussos S *Coffee Biotechnology and Quality*. Springer, Dordrecht.
Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.
Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
Sharangi AB and Acharya SK. 2008. *Quality management of Horticultural crops*. Agrotech Publishing House, Udaipur; ISBN: 81-8321-090-2.
Srivastava HC, Vatsaya and Menon, KKG. 1986. *Plantation Crops – Opportunities and Constraints*. Oxford and IBH.
Thampan PK. 1981. *Hand Book of Coconut Palm*. Oxford and IBH.

I. Course Title : Production of Spice Crops

II. Course Code : PSM 502

III. Credit Hours : (2+1)

IV. Why this course ?

Spice crops play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers. This course will impart theoretical as well as hands-on experience to the learner on scientific production technology of various spice crops in Indian perspectives. It will provide comprehensive knowledge in this regard.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on various aspects of production technology of spice crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Spice Crops	I Role of spice crops
		II Classification of spice crops
2	Production Technology	I Varietal wealth

No	Blocks	Units
		II Propagation and nursery management III Agro techniques
3	Harvest and Post harvest management	I Maturity indices and harvest II Post harvest management

VI. Theory

Block 1: Importance of spice crops

Unit 1: Role of Spice crops: Introduction, importance of spice crops, pharmaceutical significance, historical accent, present status – national and international, future prospects, role of Spices board and other development agencies.

Unit 2: Classification of spice crops: Major spices, minor spices, seed spices, tree spices, herbal spices.

Block 2: Production Technology

Unit 1: Varietal wealth: Botany and taxonomy, species, cultivars, commercial varieties/ hybrids in spice crops.

Unit 2: Propagation and nursery management: Seed, vegetative and micro-propagation methods, nursery techniques and nursery management practices.

Unit 3: Agro techniques: Climatic and soil requirements, site selection, layout, sowing/ planting times and methods, seed rate and seed treatment, nutritional and irrigation requirements, intercropping, mixed cropping, intercultural operations, weed control, mulching, plant protection, precision farming, physiological disorders, protected cultivation.

Block 3: Harvest and Post harvest management

Unit 1: Maturity indices and harvest: Maturity indices, harvesting methods, harvesting seasons, mechanized harvesting.

Unit 2: Post harvest management: Post harvest management including primary processing, grading, packaging and storage, GMP in major spice crops.

Crops

Black pepper, small and large Cardamom, Turmeric, Ginger, Garlic, Coriander, Fenugreek, Cumin, Fennel, Ajwain, Saffron, Vanilla, Nutmeg, Clove, Cinnamon, Allspice, Tamarind, Garcinia

VII. Practical

- Identification of seeds and plants;
- Botanical description of plant;
- Varietal features;
- Planting material production;
- Field layout and method of planting;
- Cultural practices;
- Harvest maturity, harvesting;
- Drying, storage, packaging;
- Primary processing;

- GAP in spice crops;
- GMP in spice crops;
- Short term experiments on spice crops;
- Exposure visits to spice farms, research institutes.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Develop the technical skill in commercial cultivation of spice crops
- Be able to start spice-based enterprises

X. Suggested Reading

Agarwal S, Sastry EVD and Sharma RK. 2001. *Seed Spices: Production, Quality, Export.* Pointer Publ.

Arya PS. 2003. *Spice Crops of India.* Kalyani.

Bose TK, Mitra SK, Farooqi SK and Sadhu MK. Eds. 1999. *Tropical Horticulture.* Vol.I. Naya Prokash.

Chadha KL and Rethinam P. Eds. 1993. *Advances in Horticulture.* Vols. IX-X. *Plantation Crops and Spices.* Malhotra Publ. House.

Gupta S. Ed. *Hand Book of Spices and Packaging with Formulae.* Engineers India Research Institute, New Delhi.

Kumar NA, Khader P, Rangaswami and Irulappan I. 2000. *Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants.* Oxford and IBH.

Nybe EV, Miniraj N and Peter KV. 2007. *Spices.* New India Publ. Agency.

Parthasarthy VA, Kandiannan V and Srinivasan V. 2008. *Organic Spices.* New India Publ. Agency.

Peter KV. 2001. *Hand Book of Herbs and Spices.* Vols. I-III. Woodhead Publ. Co. UK and CRC USA.

Ponnuswami V *et al.* 2018. *Medicinal Herbs and Herbal Cure.* Narendra Publishing House, New Delhi.

Pruthi JS. Ed. 1998. *Spices and Condiments.* National Book Trust.

Pruthi JS. 2001. *Minor Spices and Condiments- Crop Management and Post HarvestTechnology.* ICAR.

Purseglove JW, Brown EG, Green CL and Robbins SRJ. Eds. 1981. *Spices.* Vols. I, II. Longman.

Ramachandra *et al.* 2018. *Breeding of Spices and Plantation crops.* Narendra Publishing House, New Delhi.

Ravindran PN. 2000. *Black pepper*, *Piper nigrum*. CRC press.

Ravindran PN. 2002. *Cardamom, the genusElettaria.* CRC press

Ravindran PN. 2003. *Cinnamon and cassia.* CRC press

Ravindran PN. 2004. *Ginger, the genus Zingiber*. CRC press

Ravindran PN. 2007. *Turmeric, the genus curcuma.* CRC press

Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI

Shanmugavelu KG, Kumar N and Peter KV. 2002. *Production Technology of Spices and Plantation Crops.* Agrobios.

Sharangi AB, Datta S and Deb P. 2018. Spices "*Agrotechniques for quality produce*". Apple Acadamic Press (Tylor and Francis Groups), New Jersey, USA.

Sharangi AB. 2018. Indian Spices "*The legacy, production and processing of India's treasured export.*" Springer International publishing AG, Part of Springer Nature 2018, Cham, Switzerland.

Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
Sharangi AB and Acharya SK. 2008. *Quality Management of Horticultural crops*. Agrotech Publishing House, Udaipur; ISBN: 81-8321-090-2.
Thamburaj S and Singh N. Eds. 2004. *Vegetables, Tuber Crops and Spices,* ICAR.
Tiwari RS and Agarwal A. 2004. *Production Technology of Spices*. International Book Distr. Co.

I. Course Title : Production of Medicinal and Aromatic Crops

II. Course Code : PSM 503

III. Credit Hours : (2+1)

IV. Why this course ?

Medicinal and aromatic crops play an important role in the national economy of India. These crops also provide health security to all. This course will impart theoretical as well as hands-on experience to the learner on scientific production technology of various medicinal and aromatic crops in Indian perspectives. It will provide comprehensive knowledge in this regard.

V. Aim of the course

To impart comprehensive knowledge on the production technology of important medicinal and aromatic crops

The course is organized as follows:

No	Blocks	Units
1	Importance of Medicinal and Aromatic Crops	I Classification of medicinal and aromatic crops
		II Medicinal plant based industry
		III Aromatic plant based industry
2	Production technology	I Varietal wealth
		II Propagation and nursery management
		III Agro techniques
3	Harvest and Post harvest management	I Maturity indices and harvest
		II Post harvest management

Theory

Block 1: Importance of Medicinal and Aromatic Crops

Unit 1: Classification of medicinal and aromatic crops: Importance of medicinal plants, Importance of aromatic plants, Role in national economy, utility sectors of medicinal and aromatic crops, classification of medicinal and aromatic crops, role of institutions, Medicinal Plant Board and NGO's in research and development of medicinal and aromatic crops.

Unit 2: Medicinal and plant based industry: Indian system of medicine, traditional systems of medicine, tribal medicine, medicinal industry, source of medicinal plants, area, production, export and import of major crops, problems, prospects and challenges, IPR issues.

Unit 3: Aromatic plant based industry: Essential oils, classification, physical and chemical properties and storage of essential oils. Indian perfumery industry,area, production, export and import status of major aromatic crops, history and advancements, problems, prospects and challenges, IPR issues.

Block 2: Production technology of medicinal and aromatic crops

Unit 1: Varietal wealth: Botany and taxonomy, species, cultivars, commercial varieties/ hybrids in medicinal and aromatic crops.

Unit 2: Propagation and nursery management: Seed, vegetative and micro-propagation methods, nursery techniques and nursery management practices.

Unit 3: Agro techniques: Climatic and soil requirements, site selection, layout, sowing/ planting times and methods, seed rate and seed treatment, nutritional and irrigation requirements, intercropping, mixed cropping, intercultural operations, weed control, mulching, plant protection.

Block 3: Harvest and Post harvest management

Unit 1: Maturity indices and harvest: Maturity indices, harvesting methods, harvesting seasons in medicinal and aromatic crops.

Unit 2: Post harvest management: Post harvest management including primary processing, extraction, grading, packaging and storage, GMP in medicinal and aromatic crops.

Crops

A. Medicinal crops: Senna, periwinkle, medicinal coleus, aswagandha, glory lily, sarpagandha, *Dioscorea* sp., *Aloe vera*, *Andrographis paniculata, Digitalis,* medicinal solanum, isabgol, opium poppy, safedmusli, *Stevia rebaudiana, Mucuna pruriens, Piper longum, Plumbago zeylanica*

B. Aromatic crops: Palmarosa, lemongrass, citronella, vetiver, mentha, patchouli, sweet flag, jasmine, geranium, artemisia, lavender, *Ocimum* sp., eucalyptus, sandal

VI. Practical

- Description of botanical and varietal features;
- Nursery techniques;
- Lay out and planting;
- Manuring practices;
- Maturity standards;
- Harvesting;
- Primary processing;
- Extraction of oils;
- Herbarium preparation;
- Project preparation for establishing herbal gardens;
- GAP in medicinal and aromatic crops;
- GMP in medicinal and aromatic crops;
- Exposure visits to institutes, herbal gardens and industries.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

VIII. Learning outcome

After successful completion of this course, the students are expected to:

- Develop the technical skill in commercial cultivation of medicinal and aromatic crops
- Be able to start medicinal and aromatic crop-based enterprises

IX. Suggested Reading

Atal CK and Kapur BM. 1982. *Cultivation and Utilization of Medicinal Plants*. RRL, CSIR, Jammu.

Barche S. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi.

Das K. 2013. *Essential oils and their applications*. New India Publishing Agency, New Delhi

Farooqi AA and Sriram AH. 2000. *Cultivation Practices for Medicinal and Aromatic Crops*. Orient Longman Publ.

Farooqi AA, Khan MM and Vasundhara M. 2001. *Production Technology of Medicinal and Aromatic Crops*. Natural Remedies Pvt. Ltd.

Gupta RK. 2010. *Medicinal and Aromatic plants*. CBS publications.

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Khan IA and Khanum A. 2001. *Role of Biotechnology in Medicinal and Aromatic Plants*. Vol. IX. Vikaaz Publ.

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Panda H. 2002. *Medicinal Plants Cultivation and their Uses*. Asia Pacific Business Press.

Panda H. 2005. *Aromatic Plants Cultivation, Processing and Uses*. Asia Pacific Business Press.

Ponnuswami *et al*. 2018. *Medicinal Herbs and Herbal Cure*. Narendra Publishing House, New Delhi.

Prajapati SS, Paero H, Sharma AK and Kumar T. 2006. *A Hand book of Medicinal Plants*. Agro Bios.

Ramawat KG and Merillon JM. 2003. *BioTechnology – Secondary Metabolites*. Oxford and IBH.

Shankar SJ. 2018. *Comprehensive post harvest technology of flowers, medicinal and aromatic plants*. Narendra Publishing House, New Delhi.

Skaria PB, Samuel M, Gracy Mathew, Ancy Joseph, Ragina Joseph. 2007. *Aromatic Plants*. New India Publ. Agency.

I. Course Title : Breeding of Plantation and Spice Crops

II. Course Code : PSM 504

III. Credit Hours : (2+1)

IV. Why this course ?

Plantation and spice crops play an important role in the national economy of India. For maximizing the production, productivity and quality of plantation and spice crops, fundamental knowledge on breeding methods of the major crops is essential. This course will impart theoretical as well as hands-on experience to the learner on reproductive biology, breeding methods and breeding achievements in various plantation and spice crops

V. Aim of the course

To impart comprehensive knowledge on the principles and practices in the breeding of important plantation and spice crops

The course is organized as follows:

No	Blocks	Units
1	Genetic diversity	I Species and cultivar diversity II Germplasm evaluation
2	Crop improvement	I Breeding objectives II Breeding methods
3	Breeding achievements and future thrusts	I Breeding achievements II Future thrusts

VI. Theory

Block 1: Genetic diversity

Unit I: Species and cultivar diversity: Floral and reproductive biology, cytogenetics, male sterility, incompatibility, wild and cultivated species, popular cultivars.

Unit II: Germplasm evaluation: Survey, collection, conservation and evaluation of germplasm.

Block 2: Crop improvement

Unit I: Breeding objectives: Breeding objectives/ goals on the basis of yield, quality, stress tolerance, adaptation.

Unit II: Breeding methods: Approaches for crop improvement, introduction, selection, hybridization, mutation breeding, polyploidy breeding, improvement of quality traits, resistance breeding for biotic and abiotic stresses.

Block 3: Breeding achievements and future thrusts

Unit I: Breeding achievements: Breeding achievements in terms of released varieties, parentage, salient features.

Unit II: Future thrusts: Molecular breeding and biotechnological approaches, marker-assisted selection, bioinformatics, breeding for climate resilience

Crops

A. Plantation crops: Coconut, Arecanut, Cashew, Cocoa, Rubber, Oil palm, Coffee, Tea, Palmyrah, Betel vine

B. Spice crops: Black pepper, small and large cardamom, Ginger, Turmeric, Fenugreek, Coriander, Fennel, Cumin, Ajwain, Garlic, Nutmeg, Cinnamon, Clove, Allspice, Garcinia, Tamarind

VII. Practical

- Characterization and evaluation of germplasm;
- Floral biology, anthesis; pollen behaviour, fruit set;
- Practices in hybridization, selfing and crossing techniques;
- Polyploidy breeding;
- Mutation breeding;
- Induction of somaclonal variation and screening the variants;
- Evaluation of biometrical traits and quality traits;
- Salient features of improved varieties and cultivars;
- Screening for biotic and abiotic stresses;

- Bioinformatics;
- Exposure visits to research institutes for plantation and spice crops.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Develop the technical skill in breeding of plantation and spice crops
- Be able to start plantation and spice crop-based seed production/ nursery centres

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

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Devi AR, Sharangi AB, Acharya SK and Mishra GC. 2017. *Coriander in Eastern India: The landraces and genetic diversity*. Krishi Sanskriti Publications. New Delhi. ISBN: 978-93-85822-48-3.

E-manual on Advances in Cashew Production Technology. ICAR –Directorate of Cashew Research, Puttur –574 202, DK, Karnataka

Harver AE. 1962. *Modern Coffee Production.* Leonard Hoff.

Kumar N. 2017. *Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants*.CBS Publishers.

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Ponnuswami *et al*. 2018. *Spices*. Narendra Publishing House,New Delhi.

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Ramachandra *et al*. 2018. *Breeding of Spices and Plantation Crops.* Narendra Publishing House,New Delhi

Ravindran PN. 2002. *Cardamom, the genus Elettaria*. CRC press

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Ravindran PN. 2007. *Turmeric, the genus Curcuma*. CRC press

Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI
Sera T, Soccol CR, Pandey A, Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
Sethuraj MR and Mathew NT. 1992.*Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.
Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.
Thampan PK. 1981. *Hand Book of Coconut Palm*. Oxford and IBH.

I. Course Title : Breeding of Medicinal and Aromatic Crops
II. Course Code : PSM 505
III. Credit Hours : (1+1)

IV. Why this course ?

Medicinal and aromatic crops play an important role in the national economy of India. For maximizing the production, productivity and quality of medicinal and aromatic crops, fundamental knowledge on breeding methods of the major crops is essential. This course will impart theoretical as well as hands-on experience to the learner on reproductive biology, breeding methods and breeding achievements in various medicinal and aromatic crops.

V. Aim of the course

To impart comprehensive knowledge on the principles and practices in the breeding of important medicinal and aromatic crops.

The course is organized as follows:

No	Blocks	Units
1	Genetic diversity	1. Species and cultivar diversity 2. Germplasm evaluation
2	Crop improvement	1. Breeding objectives 2. Breeding methods
3	Breeding achievements and future thrusts	1. Breeding achievements 2. Future thrusts

VI. Theory

Block 1: Genetic diversity

Unit 1: Species and cultivar diversity: Floral and reproductive biology, cytogenetics, male sterility, incompatibility, wild and cultivated species, popular cultivars.

Unit 2: Germplasm evaluation: Survey, collection, conservation and evaluation of germplasm, IPR issues.

Block 2: Crop improvement

Unit 1: Breeding objectives: Breeding problems in medicinal and aromatic crops. Genetics of active principles, breeding objectives/ goals on the basis of yield, quality, stress tolerance, adaptation.

Unit 2: Breeding methods: Approaches for crop improvement, introduction, selection, hybridization, mutation breeding, polyploidy breeding, improvement of quality traits, resistance breeding for biotic and abiotic stresses.

Block 3: Breeding achievements and future thrusts

Unit 1: Breeding achievements: Breeding achievements in terms of released varieties, parentage, salient features.

Unit 2: Future thrusts: Molecular breeding and biotechnological approaches, marker-assisted selection, bioinformatics, breeding for climate resilience.

Crops

A. Medicinal crops: *Cassia angustifolia*, *Catharanthus roseus*, *Gloriosa superba, Coleus forskohlii*, *Stevia rebaudiana*, *Withania somnifera*, *Papaver somniferum*, *Plantago ovata*, *Chlorophytum* sp., *Rauvolfia serpentina*, *Aloe vera, Piper longum, Plumbago zeylanica*

B. Aromatic crops: Mint, geranium, patchouli, lemon grass, palmarosa, citronella, vetiver, Artemisia, ocimum, lavender, *Kaempferia galanga,* eucalyptus

VII. Practical

- Description of botanical features;
- Cataloguing of cultivars, varieties and species in medicinal and aromatic crops;
- Floral biology;
- Selfing and crossing;
- Evaluation of hybrid progenies;
- Induction of economic mutants;
- High alkaloid and high essential oil mutants;
- Evolution of mutants through physical and chemical mutagens;
- Introduction of polyploidy;
- Screening of plants for biotic and abiotic stress;
- *In-vitro* breeding in medicinal and aromatic crops.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- Develop the technical skill in breeding of medicinal and aromatic crops
- Be able to start medicinal and aromatic crop-based seed production/ nursery centres

X. Suggested Reading

Chadha KL and Gupta, R. 1995. *Advances in Horticulture*. Vol. XI. Malhotra Publ. House.

Farooqi AA, Khan MM and Vasundhara M. 2001. *Production Technology of Medicinal and Aromatic Crops*. Natural Remedies Pvt. Ltd.

Gupta R.K. 2010. *Medicinal and Aromatic plants*. CBS publications

Jain SK. 2000. *Medicinal Plants*. National Book Trust.

Julia F and Charters MC. 1997. *Major Medicinal Plants – Botany, Cultures and Uses*. Thomas Publ.

Kurian A and Asha Sankar M. 2007. *Medicinal Plants*. Horticulture Science Series, New India Publ. Agency.

Ponnuswami *et al*. 2018. *Blossom biology of Horticultural crops*. Narendra Publishing House, New Delhi

Ponnuswami *et al*. 2018. *Botany of Horticultural crops*. Narendra Publishing House, New Delhi

Ponnuswami *et al*. 2018. *Medicinal Herbs and Herbal Cure*. Narendra Publishing House, New Delhi

Waghulkar VM. 2012. *Quality assurance techniques in pharmaceuticals*. New India Publishing Agency, New Delhi

I. Course Title : Systematics of Plantation and Spice Crops

II. Course Code : PSM 506

III. Credit Hours : (1+1)

IV. Why this course ?

Plantation and spice crops play an important role in the national economy of India. For the crop improvement programme of these crops, fundamental knowledge on origin and development, evolutionary process, taxonomy and cytogenetics and is most essential. This course will impart theoretical knowledge to the learner on the origin and distribution, evolutionary process, taxonomy and cytogenetics of various plantation and spice crops.

V. Aim of the course

To impart basic knowledge on the origin and development, evolutionary process, taxonomy, chemotaxonomy, cytogenetics and genetic resources of plantation and spice crops.

The course is organized as follows:

No	Blocks	Units
1	Origin and evolution	1. Centre of origin 2. Systematics
2	Genetic diversity	1. Species and cultivar diversity 2. Germplasm
3	Cataloguing	1. Descriptors 2. DUS guidelines

VI. Theory

Block 1: Origin and evolution

Unit I: Centre of origin: Centre of origin, distribution, taxonomical status, phylogeny.

Unit II: Systematics: Botany, cytology, ploidy status, sex forms, flowering and pollination biology, cytogenetics.

Block 2: Diversity

Unit I: Species and cultivar diversity: Wild and related species, cultivars.

Unit II: Germplasm: Indigenous and exotic germplasm.

Block 3: Cataloguing

Unit I: Descriptors: Biovarsity/ NBPGR descriptors and their salient features.

Unit II: DUS guidelines: DUS guidelines, molecular aspects of systematics.

Crops

A. Plantation crops: Coconut, Arecanut, Oil Palm, Tea, Coffee, Cocoa, Cashew, Rubber, Betel Vine

B. Spice crops: Black Pepper, Cardamom, Ginger, Turmeric, Nutmeg, Cinnamon, Clove, Vanilla, Coriander, Fennel, Cumin, Fenugreek, Garlic

VII. Practical

- Genus, species and cultivar features of various plantation and spice crops;
- Characterization based on descriptors;
- Characterization based on DUS guidelines;
- Study of sex forms and floral biology;
- Study of molecular markers;
- Exposure visits to national institutes including NBPGR.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- have thorough understanding on the systematics of plantation and spice crops

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press

Chadha KL and Gupta R. 1995. *Advances in Horticulture*. Vol. XI. Malhotra Publ. House.

Charles B. 1993. *Discussions in Cytogenetics*. Prentice Hall Publications,

Diwan AP and Dhakad NK. 1996. *Genetics and Development*. Anmol Publications Private Limited, New Delhi.

E-manual on Advances in Cashew Production Technology. ICAR –Directorate of Cashew Research, Puttur –574 202, DK, Karnataka

Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.

Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.

Pillay PNR. 1980. *Handbook of Natural Rubber Production in India.* Rubber Research Institute, Kottayam. pp.668

Ponnuswami *et al.* 2018. Blossom biology of Horticultural crops. Narendra Publishing House, New Delhi

Ponnuswami *et al.* 2018. Botany of Horticultural crops. Narendra Publishing House, New Delhi

Ravindran PN. 2000. *Black pepper*, *Piper nigrum*. CRC press

Ravindran PN. 2002. *Cardamom, the genusElettaria.* CRC press

Ravindran PN. 2003. *Cinnamon and cassia.* CRC press

Ravindran PN. 2004. *Ginger, the genus Zingiber*. CRC press

Ravindran PN. 2007. *Turmeric, the genus curcuma.* CRC press

Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI

Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.

Sethuraj MR and Mathew NT. 1992.*Natural Rubber: Biology, Cultivation and Technology* (*Developments in Crop Science*). Elsevier Science.

Sharma G. 2009. *Systematics of fruit Crops*. New India Publishing House, India.

Strickberger MW. 2005. *Genetics* (III Ed). Prentice Hall, New Delhi, India

Tamarin RH. 1999. *Principles of Genetics*. Wm. C. Brown Publishers

I. Course Title : Systematics of Medicinal and Aromatic Crops

II. Course Code : PSM 507

III. Credit Hours : (1+1)

IV. Why this course ?

Medicinal and aromatic crops play an important role in the national economy of India. For the crop improvement programme of these crops, fundamental knowledge on origin and development, evolutionary process, taxonomy and cytogenetics is most essential. This course will impart theoretical knowledge to the learner on the origin and distribution, evolutionary process, taxonomy and cytogenetics of various medicinal and aromatic crops.

V. Aim of the course

To impart basic knowledge on the origin and development, evolutionary process, taxonomy, cytogenetics and genetic resources of medicinal and aromatic crops.

The course is organized as follows:

No	Blocks	Units
1	Origin and evolution	I Centre of origin
		II Systematics
2	Genetic diversity	I Species and cultivar diversity
		II Germplasm
3	Cataloguing	I Descriptors
		II DUS guidelines

VI. Theory

Block 1: Origin and evolution

Unit I: Centre of origin: Centre of origin, distribution, taxonomical status, phylogeny, chemotaxonomy.

Unit II: Systematics: Botany, cytology, ploidy status, sex forms, flowering and pollination biology, cytogenetics.

Block 2: Diversity

Unit I: Species and cultivar diversity: Wild and related species, cultivars.

Unit II: Germplasm: Indigenous and exotic germplasm.

Block 3: Cataloguing

Unit I: Descriptors: Biovarsity/ NBPGR descriptors and their salient features.

Unit II: DUS guidelines: DUS guidelines, molecular aspects of systematics.

Crops

1. Medicinal crops: Opium poppy, Isabgol, Aswagandha, Senna, Medicinal coleus,Glory Lily, Periwinkle, Sarpagandha, Long Pepper, Stevia, Safed musli, *Plumbago zeylanica*

2. Aromatic crops: Lemongrass, Citronella, Palmarosa, Vetiver, Mint, Patcholi, Geranium, Ocimum, Rosemary, Lavender, *Kaempferia galanga*, Eucalyptus

VII. Practical

- Genus, species and cultivar features of various medicinal and aromatic crops;

- Characterization based on descriptors;
- Characterization based on DUS guidelines;
- Study of sex forms and floral biology;
- Study of molecular markers;
- Exposure visits to national institutes including NBPGR.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to have thorough understanding on the systematics of medicinal and aromatic crops

X. Suggested Reading

Birel Shah and Seth AK. 2005. *Text book of Pharmacognosy and Phytochemistry*. CBS Publishers and distributors, New Delhi.

Charles Burnham. 1993. *Discussions in Cytogenetics*. Prentice Hall Publications

Diwan AP and Dhakad NK. 1996. *Genetics and Development*. Anmol Publications Private Limited, New Delhi.

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Gupta RK. 2010. *Medicinal and Aromatic plants*. CBS publications

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Ponnuswami *et al*. 2018. *Blossom biology of Horticultural crops*. Narendra Publishing House, New Delhi.

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Ranjal Kandall. *Bioactive compounds and genomic study of medicinal plants*. LAMBERT Academic Publishing

Sharma G. 2009. *Systematics of fruit Crops*. New India Publishing House, India.

Skaria P Baby *et al*. 2007. *Aromatic Plants*. New India Publ. Agency.

Strickberger MW. 2005. *Genetics* (III Ed). Prentice Hall, New Delhi, India

Tamarin RH. 1999. *Principles of Genetics*. Wm. C. Brown Publishers.

Thakur RS, Pauri HS and Hussain A. 1989. *Major Medicinal Plants of India*. CSIR.

I. Course Title : Underexploited Plantation, Spice, Medicinal and Aromatic Plants

II. Course Code : PSM 508

III. Credit Hours : (2+0)

IV. Why this course ?

There are many number of underexploited plantation, spice, medicinal and aromatic crops which are becoming important in line with the major ones. They could very well be the major crops of tomorrow. This course will impart comprehensive knowledge to the learner on the importance and scientific production technology of various under utilised plantation, spice, medicinal and aromatic plants in India.

V. Aim of the course

To facilitate understanding on the importance and cultivation of underutilized and lesser known plantation, spice, medicinal and aromatic plants.

The course is organized as follows:

No	Blocks	Units
1	Importance and status	I Importance and uses II Status and future prospects
2	Production technology	I Propagation and varieties II Agro techniques
3	Harvest and post harvest management	I Harvest indices II Post harvest management

VI. Theory

Block 1: Importance and status

Unit I: Importance and Uses: Introduction, importance, economic parts used, traditional uses.

Unit II: Status and future prospects: Present status, origin, distribution and future prospects of under exploited PSMAs.

Block 2: Production technology

Unit I: Propagation and varieties: Propagation and nursery techniques, species varieties.

Unit II: Agro techniques: Climatic and soil requirements, planting and after care, weed and water management, manuring, plant protection.

Block 3: Harvest and post harvest management

Unit I: Harvest indices: Maturity indices, harvesting time, techniques, crop duration.

Unit II: Post harvest management: Primary processing, extraction and value addition, storage, active ingredients.

Crops

A. Plantation crops: Wattle, minor species of Areca, Coffea, Hevea

B. Spice crops: *Illicium verum*, *Myristica malabarica, M. beddomei, Cinnamomum tamala*, *C. malabatrum*, *Xanthoxylum* sp., *Curcuma caesia, C. aromatica, C. zedoaria, C. amada, Anethum graveolense, Hyssopus officinalis*, *Eringiumfoetidum, Pimpinella anisum, Artocarpus lacucha.*

C. Medicinal plants: *Flacourtia montana*, *Plectranthus aromaticus*, *Adhatoda* sp. *Hemidesmus indicus*, *Tinospora cordifolia*, *Gymnema sylvestre*, *Psoralea corylifolia*, *Eclipta alba*, *Aristalochia indica*, *Morinda citrifolia*, *Caesalpinia sappan*, *Terminalia chebula, T. bellerica, Phyllanthus amarus, Strychnos nuxvomica, S. indicum, S. xanthocarpum*, *Aegle marmelos*, *Alpinia* sp., *Hibiscus subdariffa, Anthocephalus kadamba, Costus* sp., *Kaempferia rotunda, K. parviflora, Picrorrhiza kurroa, Nardostachis jatamansi,Valeriana officinalis*, *Swertia chiraita, Aconitum* sp., *Salvia officinalis*, *Centella asiatica, Bixa orellana, Bacopa monnieri*

D. Aromatic plants: *Bursera* sp., *Commiphora wightii*, *Ocimum kilimandjaricum, Melaleuca, Michaelia champaka*, *Rosa damascena, Cananga odorata,* marjoram, chamomile

VII. Practical

- Botanical characteristics of species and varieties of various underexploited plantation, spice, medicinal and aromatic plants;
- Economic parts and their products;
- Propagation and nursery techniques;
- Harvesting and primary processing of under utilised PSMAs;
- Exposure visits to institutes, botanical gardens, herbal gardens and distillation units.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- be thorough with the importance and commercial production technology of underutilized and lesser known plantation, spice, medicinal and aromatic plants.
- be able to startunderutilized and lesser known plantation, spice, medicinal and aromatic plants-based enterprises

X. Suggested Reading

Atal CK and Kapur BM. *Cultivation and Utilization of Aromatic plants*. R.R.L. Jammu

Barche Swati. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi

Chadha KL and Gupta R. 1995. *Advance in Horticulture*. Vol. XI. *Medicinal and AromaticPlants*. Malhotra Publ. House.

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Peter KV. *Under exploited and underutilized Horticulture crops*. Volume I-IV. New India Publication Agency.

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Ponnuswami *et al*. 2018. *Botany of Horticultural crops*. Narendra Publishing House, New Delhi

Ponnuswami *et al*. 2018. *Medicinal Herbs and Herbal Cure*. Narendra Publishing House, New Delhi

Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.

Sharangi AB, Bhutia PH, Chandani Raj A and Sreenivas M. 2018. *Underexploited spice crops: Present status, agrotechnology and future research directions*. Apple Academic Press (Taylor and Francis Group), Waretown, NJ, USA, p.326.

Sivarajan VV and Balachandran I. 1994. *Ayurvedic Drugs and their Plant Sources*. Oxford and IBH.

I. Course Title : Growth and Development of Plantation, Spice, Medicinal and Aromatic Crops

II. Course Code : PSM 509

III. Credit Hours : (2+1)

IV. Why this course ?

Understanding on growth and development of plantation, spice, medicinal and aromatic crops is vital towards quality production as well as yield. Fundamental knowledge on developmental physiology, biology and biochemistry and the associated changes is most essential. This course will impart theoretical as well as hands-on experience to the learner on these aspects of PSMA crops for improving their productivity.

V. Aim of the course

To impart comprehensive knowledge on the growth, developmental stages and crop regulation to increase the productivity in PSMAs

The course is organized as follows:

No	Blocks	Units
1	Growth and development	I Stages of growth II Growth pattern III Assimilate partitioning
2	Canopy management	I Canopy management II Plant bio regulators
3	Developmental physiology and biochemistry	I Vegetative phase II Flowering and fruit set III Growth and development during stress

VI. Theory

Block 1: Growth, development, assimilate partitioning and plant bio regulators

Unit I: Stages of growth: Growth and development, definitions, components, photosynthetic productivity, different stages of growth, growth curves, growth analysis, morphogenesis in PSMAs.

Unit II: Growth pattern: in annual, semi-perennial and perennial crops, growth dimorphism, environmental impact on growth and development: effect of light, temperature, photoperiod.

Unit III: Assimilate partitioning: Assimilate partitioning during growth and development, influence of water and mineral nutrition.

Block 2: Canopy management

Unit I: Canopy management: Canopy management for conventional and high density planting pruning, training, chemicals, crop regulation for year round and off season production in PSMAs.

Unit II: Plant bio regulators: plant bio regulators- auxins, gibberellins, cytokinins, ethylene, inhibitors and retardants, basic functions, biosynthesis and role in crop growth and development.

Block 3: Developmental physiology and biochemistry

Unit I: Vegetative phase: Developmental physiology and biochemistry during dormancy, bud break, juvenility.

Unit II: Flowering and fruit set

Physiology of flowering, photoperiodism, vernalisation, effect of temperature, heat units, thermoperiodism, pollination, fertilisation, fruit set, fruit drop, fruit growth, ripening, seed development in PSMAs.

Unit III: Growth and development process during stress: Growth and development process during stress, production of secondary metabolites, molecular and genetic approaches in growth and development.

VII. Practical

- Dormancy mechanisms in seeds, seed rhizomes;
- Techniques of growth analysis;
- Evaluation of photosynthetic efficiency under different environments;
- Technologies for crop regulation in cashew, coffee, cocoa, etc.;
- Root shoot studies, flower thinning, fruit thinning;
- Crop regulation for year round production;
- Use of growth regulators in PSMA crops.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Demonstrations
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to

- have thorough understanding on growth and development of PSMA crops
- will enable them to formulate crop regulation strategies for productivity enhancement.

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press

Buchanan BW. Gruiessam and Jones, R. 2002. *Biochemistry and Molecular Biology of Plants*. John Wiley and Sons.

E- manual on Advances in Cashew Production Technology. ICAR -Directorate of Cashew Research, Puttur –574 202, DK, Karnataka

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Ravindran PN. 2003. *Cinnamon and cassia*. CRC press

Ravindran PN. 2004. *Ginger, the genus Zingiber*. CRC press

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Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI
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Salisbur FB and Ross CW. 1992. *Plant Physiology*. 4th Ed. Wadsworth Publ.
Sera T, Soccol CR, Pandey A. and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.

I. Course Title : Biochemistry of Plantation, Spices, Medicinal and Aromatic Crops

II. Course Code : PSM 510

III. Credit Hours : (2+1)

IV. Why this course ?

Postharvest physiology and biochemistry of plantation, spice, medicinal and aromatic crops contributes immensely towards quality improvement in crude as well as processed products. Fundamental knowledge on biochemistry of various crops is also essential for formulating their management practices in the field. This course will impart theoretical as well as hands-on experience to the learner on the biochemistry of PSMA crops.

V. Aim of the course

To impart comprehensive knowledge on the biochemistry, production of primary and secondary metabolites and the extraction of bioactive principles from PSMAs

The course is organized as follows:

No	Blocks	Units
1	Post harvest physiology	I Physiological and biochemical changes II Contaminants
2	Value addition	I Value added products II Quality standards
3	Extraction techniques	I Extraction techniques II Plant tissue culture

VI. Theory

Block 1: Post-harvest physiology

Unit I: Physiological and biochemical changes: Maturity indices, changes during ripening, processing, factors affecting quality. Secondary metabolites and their biosynthetic pathways, factors affecting production of secondary metabolites.

Unit II: Contaminants: Adulterants, and substitutes, sources of contamination-microbial, heavy metal, pesticide residues in PSMAs.

Block 2: Value addition

Unit I: Value added products: Fixed oils, essential oils, dyes, oleoresins, aroma chemicals and other value added products, their content, storage, medicinal and pharmacological properties, use in the food, flavour perfumery and pharmaceutical industries.

Unit II: Quality standards: Quality standards of raw materials and finished products.

Block 3: Extraction techniques

Unit I: Extraction methods: Basic and advanced extraction techniques in PSMAs-Soxhlet, SCFE, Membrane extraction. Chemical characterization-HPTLC, GCMS, LCMS, NMR.

Unit II: Plant tissue culture: Plant tissue cultures in the industrial production of bioactive plant metabolites. Cell suspension culture systems for large scale culturing of plant cells and production of secondary metabolites. Advantages of cell culture over conventional extraction techniques.

VII. Practical

- Biochemical characterisation;
- Detection of adulterants and substitutes;
- Extraction and quantification of secondary metabolites;
- Chromatographic separation of the products;
- Quality assurance;
- Testing the product;
- Exposure visit to leading industries;
- Assessment of antimicrobial properties;
- *In-vitro* production of secondary metabolites.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Demonstration
- Exposure visits

IX. Learning outcome

After successful completion of this course, the students are expected to:

- develop the technical know- how on postharvest biochemistry of plantation, spice, medicinal and aromatic crops.

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

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Tiwari C. 2018. *Antimicrobial properties of Medicinal plants*. Narendra Publishing House, New Delhi.
Trivedi C. 2004. *Herbal drugs and biotechnology*. Pointer Publishers.
Waghulkar VM. 2012. *Quality assurance techniques in pharmaceuticals*. New India Publishing Agency, New Delhi.

I. Course Title : Biodiversity and Conservation of Plantation, Spices Medicinal and Aromatic Crops

II. Course Code : PSM 511

III. Credit Hours : (2+1)

IV. Why this course ?

India is the homeland of several plantation, spice, medicinal and aromatic crops. Biodiversity conservation is considered as the primary step in protecting the gene pool available in these crops. Fundamental knowledge on centres of diversity, germplasm evaluation, documentation, data base management and cataloguing is most essential. This course will impart theoretical as well as hands-on experience to the learner on these areas.

V. Aim of the course

To impart basic knowledge on natural as well as agro bio diversity, its value and conservation strategies with respect to PSMAs.

The course is organized as follows:

No	Blocks	Units
1	Plantation and spice crops	I Biodiversity
		II Germplasm collection and quarantine
		III Documentation and cataloguing
		IV National and international issues
2	Medicinal and aromatic crops	I Biodiversity
		II Germplasm collection and quarantine
		III Documentation and cataloguing
		IV National and international issues

VI. Learning outcome

After successful completion of this course, the students are expected to develop thorough understanding on biodiversity conservation of plantation, spice, medicinal and aromatic plants.

VII. Theory

Block 1: Plantation and Spice crops

Unit I: Biodiversity: Biodiversity, issues and goals, centres of origin of Plantation and spice crops, primary and secondary centres of genetic diversity.

Unit II: Germplasm collection and quarantine: Exploration and germplasm collection, planning and logistics, exchange of germplasm, plant quarantine principles, regulations plant quarantine systems in India. Components of germplasm evaluation, descriptor lists. Conservation of genetics resources, Concept of base and active collections, long and short term storage of Plantation and spice crops, gene bank management.

Unit III: Documentation and cataloguing: Recent approaches and role of biotechnology in PGR conservation documentation and data base management, cataloguing gene bank information. Molecular markers in characterisation of plant genetic resources. GIS in biodiversity mapping.

Unit IV: National and international issues: Genetic resources management of Plantation and Spice crops in India and in International perspective. Utilization and achievements in major crops. Concepts of rarity, threat, endangerment and extinction in major plantation and spice crops. Bio diversity concerns, national and international regulations, conservation networks. Good collection practices, domestication, PPV and FRA and DUS testing. Geographical indication, Biodiversity act and biodiversity legislations.

Block II: Medicinal and aromatic crops

Unit I: Biodiversity: Biodiversity, issues and goals, centres of origin of medicinal and aromatic crops, primary and secondary centres of genetic diversity.

Unit II: Germplasm collection and quarantine: Exploration and germplasm collection, planning and logistics, exchange of germplasm, plant quarantine principles, regulations plant quarantine systems in India. Components of germplasm evaluation, descriptor lists. Conservation of genetics resources, Concept of base and active collections, long and short term storage of Plantation and spice crops, gene bank management.

Unit III: Documentation and cataloguing: Recent approaches and role of biotechnology in PGR conservation documentation and data base management, cataloguing gene bank information. Molecular markers in characterisation of plant genetic resources. GIS in biodiversity mapping.

Unit IV: National and international issues: Genetic resources management of Plantation and Spice crops in India and in International perspective. Utilization and achievements in major crops. Concepts of rarity, threat, endangerment and extinction in major plantation and spice crops. Bio diversity concerns, national and international regulations, conservation networks. Good collection practices, domestication, PPV and FRA and DUS testing. Geographical indication, Biodiversity act and biodiversity legislations.

VIII. Practical

- Collection and identification of different plantation, spice, medicinal and aromatic plants from natural sources;
- Preparation of herbarium;
- Botanical and phyto-chemical grouping of PSMAs;
- Classification of PSMAs based on plant parts used;
- Documentation of germplasm;
- Maintenance of passport data and other records;
- Field explorations;
- Detection of adulterants and substitutes in PSMAs;
- Ethno botanical studies in tribal areas;
- Planning and layout of herbal gardens;
- Exposure visits to herbaria, herbal gardens and important organisations engaged in collection and utilization of PSMAs.

IX. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Demonstrations
- Exposure visits

X. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press

Choudhari AB. *Megadiversity Conservation: Flora, Fauna and Medicinal Plants of India's hot spots.*

Devi AR, Sharangi AB, Acharya SK and Mishra GC. 2017. *Coriander in Eastern India: The landraces and genetic diversity.* Krishi Sanskriti Publications. New Delhi. ISBN: 978-93-85822-48-3.

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Kassahun Beemnet, Jemal Omar Sherif, TessemaTsion, Abate Solomon. 2009. *Production, Processing and utilization of Aromatic Plants.* EIAR.

Khan JB and Singh GP. 2012. *Biodiversity Management and Conservation* LAMBERT

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Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.

Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.

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Ponnuswami *et al*. 2018. Spices. Narendra Publishing House, New Delhi
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Rajak RC and Rai MK. *Herbal Medicines, Biodiversity and Conservation strategies*. IBH.
Ramakrishnan N. 2018. *Biodiversity in Indian Scenario*. Daya publishing house.
Sera T, Soccol CR, Pandey A, Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
Sethuraj MR and Mathew NT. 1992. *Natural Rubber: Biology, Cultivation and Technology (Developments in Crop Science)*. Elsevier Science.
Thirugnanakumar. 2018. *Genetic diversity and phenotypic stability in crop plants*. New India Publishing Agency, New Delhi
Trivedi PC. *Medicinal Plants: Utilization and Conservation.*

Course Title with Credit Load
Ph.D. (Hort.) in Plantation, Spices, Medicinal and Aromatic Crops

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
PSM 601*	Advances in Production of Plantation and Spice Crops	3+0
PSM 602*	Advances in Production of Medicinal and Aromatic Crops	3+0
PSM 603*	Recent Breeding Approaches in Plantation, Spice, Medicinal and Aromatic Crops	3+0
PSM 604	Advanced Methods in Laboratory Techniques	1+2
PSM 605	Biotechnological Approaches in PSMA Crops	3+0
PSM 606	Abiotic Stress Management in Plantation, Spice, Medicinal and Aromatic Crops	2+1
PSM 607	Organic Spice and Plantation Crops Production	2+1
PSM 608	Marketing and Export of Plantation, Spice, Medicinal and Aromatic Crops	2+1
	Minor courses	06
	Supporting courses	05
PSM 691	Seminar-I	0+1
PSM 692	Seminar-II	0+1
PSM 699	Research	0+75
	Total	**100**

*Compulsory among major courses

Course Contents
Ph.D. (Hort.) in Plantation, Spices, Medicinal and Aromatic Crops

I. Course Title : Advances in Production of Plantation and Spice Crops
II. Course Code : PSM 601
III. Credit Hours : (3+0)

IV. Why this course ?

Plantation and spice crops play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers. This course will impart knowledge to the learner on advanced scientific production technology of various plantation and spice crops in Indian perspectives. Hi-tech production technologies will be discussed in this course.

V. Aim of the course

The course is designed to provide advanced crop production techniques of various plantation and spice crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Plantation and spice Crops	I. Area, production, productivity: Indian and world scenario II. Export potential III. Promotional programmes
2	Advanced agro techniques	I. Varietal wealth and planting material production II. Mass multiplication techniques III. Hi-tech nursery techniques IV. Impact of climate change
3	Harvest and post harvest management	I. Maturity indices and harvest II. Post-harvest management III. Quality standards

VI. Theory

Block 1: Importance of Plantation and Spice Crops

Unit I: Area, production, productivity: Indian and world scenario: Role of plantation and spice crops in national economy, area-production statistics at national and international level, productivity challenges, industrial requirement of plantation and spice crops, demand-supply scenario of plantation and spice crop.

Unit II: Export potential: Export scenario, market opportunities and challenges in plantation and spice crops, global imports and exports, export of organic produce and products.

Unit III: Promotional programmes: Role of commodity boards and directorates in the development programmes of plantation and spice crops, contract farming, Farmer Producer Organizations (FPO) and Farmer Producer Companies (FPC).

Block 2: Advanced Agrotechniques

Unit I: Varietal wealth and planting material production: Cultivars and improved varieties in plantation and spice crops, mass multiplication techniques, hi-tech nursery techniques.

Unit II: Agrotechniques: Precision farming techniques, HDP systems, fertigation, chemical regulation of crop productivity, protected cultivation of high value crops, mechanization in plantation and spice crops, hydroponics, aeroponics, application of nanotechnology, robotics.

Unit III: Impact of climate change: Impact of biotic and abiotic factors on growth and productivity, climate resilient technologies in plantation and spice crops, soil health management, organic production systems.

Block 3: Harvest and postharvest management

Unit I: Maturity indices and harvest: Influence of pre and post harvest factors on quality of plantation and spice crops, pre and post harvest management techniques for improving quality, good manufacturing practices in plantation and spice sector.

Unit II: Quality standards: Domestic and international standards, HACCP, BIS standards, domestic and export grades, modern packaging techniques, export protocols.

Crops

Coconut, Arecanut, Oil palm, Cashew, Coffee, Tea, Cocoa, Rubber, Palmyrah, Black pepper, Cardamom, Ginger, Turmeric, Nutmeg, Cinnamon, Clove, Vanilla, Garcinia, Coriander, Cumin, Fennel, Fenugreek, Ajwain, Dill, Safron

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Presentation of review papers and research articles
- Exposure visits to research centres, industries

VIII. Learning outcome

After successful completion of this course, the students are expected to:

- be equipped with the latest research outcome in commercial cultivation of plantation and spice crops
- be able to start hi-tech plantation and spice crop based enterprises

IX. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press

Agarwal S, Divkarasastry EV and Sharma RK. 2001. *Seed Spices, Production, Quality and Export*. Pointer Publ.

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Barche S. 2016. *Production Technology o Spices, Aromatic, Medicinal and Plantation Crops*. New India Publishing Agency, New Delhi.

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Marsh AC, Moss MK and Murphy EW. 1977. *Composition of Food Spices and Herbs, Raw, Processed and Prepared*. Agric. Res. Serv. Hand Book 8-2. Washinton DC.

Nair MK, Bhaskararao EVV, Nambiar KKN and Nambiar MC. 1979. *Cashew*. CPCRI, Kasaragod.

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Peter KV. 2001. *Hand Book of Herbs and Spices*. Vols. I-III. Woodhead Publ. Co., UK and CRC, USA.

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Pillay PNR. 1980. *Handbook of Natural Rubber Production in India*. Rubber Research Institute, Kottayam. pp.668.

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Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2007. *Management of Horticultural Crops*. Parts I, II. New India Publ. Agency.

Purseglove JW, Brown EG, Green CL and Robbins SRJ. 1984. *Spices*. Vols. I, II. Longman.

Purseglove JW. 1968. *Tropical Crops–Dicotyledons*. Longman.

Ramachandra *et al*. 2018. *Breeding of Spices and Plantation crops*. Narendra Publishing House, New Delhi.

Ranganathan V. 1979. *Hand Book of Tea Cultivation*. UPASI, Tea Res. Stn. Cinchona.

Ravindran PN. 2003. *Cinnamon and cassia*. CRC press.

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Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI

Ravindran PN and Madhusoodanan KJ. 2002. *Cardamom, the Genus Elettaria*. CRC press.

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Sharangi AB and Acharya SK. 2008. *Quality management of Horticultural crops*. Agrotech Publishing House, Udaipur; ISBN: 81-8321-090-2

Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.

Sharangi AB, Datta S and Deb, P. 2018. *Spices: Agrotechniques for quality produce*, April, Academic Press (Tylor and Francis Groups), New Jersey, USA.

Sharangi AB. 2018. *Indian Spices: The legacy, production and processing of India's treasured export*. Springer International publishing. AG, Part of Springer Nature, 2018, Cham, Switzerland.

Srivastava HC, Vatsaya and Menon KKG. 1986. *Plantation Crops–Opportunities and Constraints*. Oxford and IBH.

Swain SC. 2018. *Precision Farming in Horticulture: Approaches and strategies*. Narendra Publishing House, New Delhi.

Thampan PK. 1981. *Hand Book of Coconut Palm*. Oxford and IBH.

Varmudy V. 2001. *Marketing of Spices*. Daya Publ. House.

Winton AL and Winton KB. 1931. *The Structure and Composition of Food*. John Wiley and Sons.

Yagna Narayan Ayer AK. 1960. *Cultivation of Cloves in India*. ICAR.

I. Course Title : Advances in Production of Medicinal and Aromatic Crops

II. Course Code : PSM 602

III. Credit Hours : (3+0)

IV. Why this course ?

Medicinal and aromatic crops play an important role in the national economy of India. They also cater to the primary health care needs of a large section of people. This course will impart knowledge to the learner on advanced scientific production technology of various medicinal and aromatic crops in Indian perspectives.

V. Aim of the course

The course is designed to provide latest developments and trends in the production technology of various medicinal and aromatic crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Importance of Medicinal and Aromatic Crops	1. Biodiversity of medicinal and aromatic crops
		2. Area, production, productivity statistics
		3. Export potential
2	Advanced Agro techniques	1. Domestication studies
		2. Varietal wealth and planting material production
		3. Agro techniques
		4. Impact of climate change
3	Harvest and post Harvest Management	1. Maturity indices and harvest
		2. Modern methods of extraction of MAPs
		3. Quality standards

VI. Theory

Block 1: Importance of Medicinal and Aromatic Crops

Unit I: Biodiversity of medicinal and aromatic crops (MAPs): Biodiversity of MAPs, conservation networks, global initiatives on medicinal plants conservation and development, World history on usage of MAPs, preference to natural products. Indian traditional wisdom and heritage, Indian herbal wealth, documentations, databases, scientific validation.

Unit II: Area, production and productivity statistics: Role of medicinal and aromatic crops in national economy, area-production statistics at national and international level, productivity challenges, Trends in food, flavouring, perfumery and cosmetic industries, requirement in the ayurvedic, pharmaceutical, perfume and cosmetic industries, demand-supply scenario of MAPs.

Unit III: Export potential: Export and import of crude drugs, standardized extracts, aromatic plants, essential oils. Intellectual Property Rights, patents. Contract farming. Role of Medicinal Plant Board in promotional programmes of MAPs.

Block 2: Advanced agro-techniques

Unit I: Domestication of medicinal and aromatic crops: Need for domestication, changes on domestication, influence of environment on secondary metabolite production, developing cultivation packages for emerging crops.

Unit II: Varietal wealth and planting material production: Cultivars and improved varieties in medicinal and aromatic crops, mass multiplication techniques, micropropagation, hi-tech nursery techniques.

Unit III: Agro techniques: Advanced research in the field of growth and development, nutrition and irrigation requirements, inter culture, mulching, weed control.

Precision farming techniques, HDP systems, fertigation, chemical regulation of crop productivity, protected cultivation of high value crops, hydroponics, aeroponics, application of nanotechnology, nano-fertilizers, nano-pesticides, robotics.

Unit IV: Impact of climate change: Impact of biotic and abiotic factors on growth, productivity and quality, climate resilient technologies in medicinal and aromatic crops, soil health management, organic production systems.

Block 3: Harvest and post harvest management

Unit I: Maturity indices and harvest: Influence of pre and post harvest factors on quality of medicinal and aromatic crops, pre and post harvest management techniques for improving quality, good manufacturing practices in herbal sector.

Unit II: Modern methods of extraction of MAPs: Advanced essential oil extraction and value addition methods in aromatic plants, advances in phytochemical extraction technologies, separation of bio-molecules, phytochemicals and drug development. Pharmacology and pharmacognosy, *in vivo* and *in-vitro* extraction of secondary metabolites, bioreactors.

Unit III: Quality standards: Quality standards in medicinal and aromatic plants, quality standards in crude drugs and finished products, use of aroma chemicals, aroma therapy, advanced research in biomedicines, nutraceuticals and natural drugs, American, European and Asian legislations on plant drugs, domestic and international standards, modern packaging techniques.

Crops

A. Medicinal crops: Coleus, Glory lily, Senna, Periwinkle, Stevia, Aswagandha, Sarpagandha, Aloe, *Phyllanthus amarus*, *Andrographis paniculata*, Isabgol, Poppy, *Digitalis* sp., *Commiphora* sp., Ipecac, Henbane, *Ocimum* sp., Centella, Bacopa, Saraca, Valerian, Jatamansi, Aconits, Ephedra and Bael.

B. Aromatic crops: Palmarosa, Lemongrass, Citronella, Vetiver, Geranium, Artemisia, Mint, Eucalyptus, Rosemary, Thyme, Patchouli, Rose, Jasmine, Lavender.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Presentation of review papers and research articles
- Exposure visits to research centres, industries

VIII. Learning outcome

After successful completion of this course, the students are expected to:

- be equipped with the latest research out come in commercial cultivation of medicinal and aromatic crops
- be able to start hi-tech medicinal and aromatic crop based enterprises

IX. Suggested Reading

Dharamvir H. 2007. *Bioactive Medicinal Plants*. Gene Tech Books.

Farooqi AA and Sriramu AH. 2000. *Cultivation Practices for Medicinal and Aromatic Crops*. Orient Longman Publ.

Farooqi AA, Khan MM and Vasundhara M. 2001. *Production Technology of Medicinal and Aromatic Crops*. Natural Remedies Pvt. Ltd.

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Ponnuswami *et al*. 2018. *Medicinal Herbs and herbal cure*. Narendra Publishing House, New Delhi.

Prajapati ND, PaeroHit SS, Sharma AK and Kumar T. 2006. *A Hand Book of Medicinal Plants*. Agro Bios.

Ramawat KG and Merillon JM. 2003. *Biotechnology–Secondary Metabolites*. Oxford and IBH.

Shankar SJ. 2018. *Comprehensive post harvest technology of flowers, medicinal and aromatic plants*. Narendra Publishing House, New Delhi.

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Sharangi AB and Datta S. 2015. *Value Addition of Horticultural crops: Recent trends and Future directions*. SPRINGER; ISBN: 978-81-322-2261-3.

Swain SC. 2018. *Precision farming in Horticulture: Approaches and strategies*. Narendra Publishing House, New Delhi.

Tiwari C. 2018. *Antimicrobial properties of Medicinal plants*. Narendra Publishing House, New Delhi.

I. Course Title : Recent Breeding Approaches in Plantation, Spice, Medicinal and Aromatic Crops

II. Course Code : PSM 603

III. Credit Hours : 3+0

IV. Why this course ?

Plantation, spice medicinal and aromatic crops (PSMA) play an important role in the national economy of India. These crops also provide livelihood security to a large section of farmers and cater to the primary health care needs of a large section of people. This course will impart knowledge to the learner on the advanced breeding approaches followed in important PSMA crops in Indian perspectives.

V. Aim of the course

The course is designed to provide knowledge on modern approaches in the breeding of various PSMA crops grown in India.

The course is organized as follows:

No	Blocks	Units
1	Plantation crops	I Genetic resources II Breeding methods III Breeding achievements
2	Spice crops	I Genetic resources II Breeding methods III Breeding achievements
3	Medicinal and Aromatic crops	I Genetic resources II Breeding methods III Breeding achievements

VI. Theory

Block 1: Plantation Crops

Unit I: Genetic resources: Evolutionary mechanisms, adaptation and domestication, genetic resources, genetic divergence, cytogenetics, variations and natural selection, types of pollination and fertilization mechanisms, sterility and incompatibility systems in Plantation crops.

Unit II: Breeding methods: Introduction and selection, chimeras, clonal selections, intergeneric, interspecific and inter-varietal hybridization, heterosis breeding, mutation and polyploidy breeding, resistance breeding to biotic and abiotic stresses, breeding for improving quality, genetics of important traits and their inheritance pattern, molecular and transgenic approaches and other biotechnological tools in crop improvement.

Unit III: Breeding achievements: Breeding objectives, ideotype breeding, breeding problems and achievements in Plantation crops.

Block 2: Spice crops

Unit I: Genetic resources: Evolutionary mechanisms, adaptation and domestication, genetic resources, genetic divergence, cytogenetics, variations and natural selection, types of pollination and fertilization mechanisms, sterility and incompatibility systems in Spice crops.

Unit II: Breeding methods: Introduction and selection, chimeras, clonal selections, intergeneric, interspecific and intervarietal hybridization, heterosis breeding, mutation and polyploidy breeding, resistance breeding to biotic and abiotic stresses, breeding for improving quality, genetics of important traits and their inheritance pattern, molecular and transgenic approaches and other biotechnological tools in crop improvement.

Unit III: Breeding achievements: Breeding objectives, ideotype breeding, breeding problems and achievements in Spice crops.

Block 3: Medicinal and aromatic crops

Unit I: Genetic resources: Evolutionary mechanisms, adaptation and domestication, genetic resources, genetic divergence, cytogenetics, variations and natural selection, chemotaxonomy, pollination and fertilization mechanisms, sterility and incompatibility systems in Medicinal and Aromatic crops.

Unit II: Breeding methods: Introduction and selection, clonal selections, intergeneric, interspecific and intervarietal hybridization, heterosis breeding, mutation and polyploidy breeding, resistance breeding to biotic and abiotic stresses, breeding for improving quality, genetics of important traits and their inheritance pattern, genetic mechanisms associated with secondary metabolites, molecular and transgenic approaches and other biotechnological tools in crop improvement.

Unit III: Breeding achievements: Specific breeding objectives in medicinal and aromatic crops, ideotype breeding, breeding problems and achievements in medicinal and aromatic crops.

Crops

A. Plantation crops: Coconut, Arecanut, Oil palm, Cashew, Coffee, Tea, Cocoa, Rubber

B. Spice crops: Black pepper, Cardamom, Ginger, Turmeric, Nutmeg, Cinnamon, Clove, Garcinia, Coriander, Cumin, Fennel, Fenugreek, Ajwain, Dill.

C. Medicinal crops: Senna, Periwinkle, Aswagandha, Isabgol, Sarpagandha, Poppy, Glory lily, Medicinal coleus, *Mucuna pruriens*, Ocimum, *Centella asiatica*, *Bacopa monnieri*, *Andrographis paniculata*, *Aloe vera*, *Phyllanthus amarus*, Eucalyptus, Bael, Henbane.

D. Aromatic crops: Lemongrass, Palmarosa, Citronella, Vetiver, Mint, Sweet basil, Lavender, Geranium, Patchouli, Artemisia, Rosemary, Thyme, Sage, Marjoram, Fever few.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Presentation of review papers and research articles
- Exposure visits to research centres, PSMA crop based industries

VIII. Learning outcome

After successful completion of this course, the students are expected to:

- be equipped with the latest research outcome in crop improvement of PSMA crops
- be able to start hi-tech PSMA crop based seed/ planting material production programmes

IX. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Agarwal S, Divkarasastry EV and Sharma RK. 2001. *Seed Spices, Production, Quality and Export*. Pointer Publ.

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Chadha KL and Gupta R. 1995. *Advances in Horticulture*. Vol.XI. Malhotra Publ. House.
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Choudappa P, Anitha K, Rajesh MK and Ramesh SV. 2017. *Biotechnology of Plantation Crops*. Daya Publishing House, New Delhi.
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I. Course Title : Advances in Laboratory Techniques for Psma Crops

II. Course Code : PSM 604

III. Credit Hours : (1+2)

IV. Why this course ?

Plantation, spice, medicinal and aromatic crops demand specific post harvest management and value addition. At each step it has to undergo quality assessment using modern equipment and machinery. Export standards are also based on stringent quality parameters. This course is designed to make the learner well versed with modern analytical methods, instruments and machinery used in quality analyses.

V. Aim of the course

To equip the students with the latest laboratory techniques required for assessing the quality of PSMA crops.

The course is organised as follows

No	Blocks	Units
1	Plantation Crops	I Physiological and biochemical changes II Contaminants III Value addition
2	Spice Crops	I Physiological and biochemical changes II Contaminants III Value addition

No	Blocks	Units
3	Medicinal and Aromatic Crops	I Secondary metabolites and their biosynthetic pathways II Contaminants III Value addition

VI. Theory

Block 1: Plantation Crops

Unit I: Physiological and biochemical changes: Physiological and biochemical changes during maturity and ripening including post harvest changes. Factors influencing quality.

Unit II: Contaminants: Adulterants, substitutes, sources of contamination: microbial, heavy metal, pesticide residues.

Unit III: Value addition: Fixed oils, value added products, grading, storage, transportation.

Block 2: Spice Crops

Unit I: Physiological and biochemical changes: Physiological and biochemical changes during maturity and ripening including Post harvest changes. Factors influencing quality.

Unit II: Contaminants: Adulterants, substitutes, sources of contamination: microbial, heavy metal, pesticide residues.

Unit III: Value addition: Fixed oils, essential oils, value added products, grading, storage, transportation.

Block 3: Medicinal and aromatic crops

Unit I: Secondary metabolites and their biosynthetic pathways, factors affecting production of secondary metaboiltes, changes during maturity, harvesting and processing.

Unit II: Contaminants: Adulterants, substitutes, contamination: microbial, heavy metal, pesticide residues.

Unit III: Value addition: Fixed oils, essential oils, oleoresins, concretes, absolutes, dyes, natural colours, aroma chemicals, grading, storage, transportation. Quality standards of raw materials and finished products.

VII. Practical

- Sampling techniques in PSMA crops or their parts;
- Solvent extraction of spices and medicinal plants;
- Detection of adulterants and substitutes;
- Extraction of secondary metabolites from medicinal crops;
- Qualitative analyses of secondary metabolites;
- Quantitative estimation of secondary metabolites;
- Preparation of plant extracts;
- Chromatographic separation of extracts;
- Thin layer chromatography;
- Soxhlet extraction;

- Super critical fluid extraction;
- Determination of physical and chemical properties of essential oils;
- Flavor profile of essential oils by gas chromatography;
- Chemical characterization by HPTLC;
- Chemical characterization by GCMS;
- Chemical characterization by LCMS;
- Chemical characterization by NMR;
- Bioassay and High Throughput Screening;
- Techniques for assessment of antimicrobial property;
- Techniques for assessment of antioxidant property, pesticide residue analyses;
- Determination of heavy metals by flame photometry;
- Plant tissue cultures in the industrial production of bioactive plant metabolites;
- Exposure visit to leading medicinal and aromatic industries, accredited quality control labs.

VIII. Learning outcome

After completion of this course, the student will be equipped in

- the modern analytical methods of biochemistry
- handling of equipments and machinery used in biotechnology, processing and value addition

IX. Suggested Reading

Barche S. 2016. *Production technology of spices, aromatic, medicinal and plantation crops*. New India Publishing Agency, New Delhi.

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Shankar SJ. 2018. *Comprehensive post harvest technology of flowers, medicinal and aromatic plants*. Narendra Publishing House, New Delhi.

Shukla Y.M. 2009. *Plant secondary metabolites*. New India Publishing Agency, New Delhi.

Parimelzhagan T. 2013. *Turning plants into medicines: Novel approaches*. New India Publishing Agency, New Delhi.

Tiwari C. 2018. *Antimicrobial properties of Medicinal plants*. Narendra Publishing House, New Delhi.

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I. Course Title : Biotechnological Approaches in Plantation, Spice, Medicinal and Aromatic Crops

II. Course Code : PSM 605

III. Credit Hours : (3 +0)

IV. Why this course ?

Tools of biotechnology are widely used in crop improvement, crop management, crop protection and post harvest management of PSMA crops. This course is designed to impart knowledge on advanced biotechnological tools used in various spheres of plantation, spices, medicinal and aromatic crops.

V. Aim of the course

The main objective of the course is to impart to the learner, knowledge on advanced biotechnological tools used in various spheres of plantation, spices, medicinal and aromatic crops.

The course is organized as follows:

No	Blocks	Units
1	Plantation Crops	I *In-vitro* mass multiplication techniques II *In-vitro* breeding III Transgenic crops
2	Spice Crops	I *In-vitro* mass multiplication techniques II *In-vitro* breeding III Transgenic crops
3	Medicinal and Aromatic Crops	I *In-vitro* mass multiplication techniques II *In-vitro* breeding III Transgenic crops IV *In-vitro* production of secondary metabolites

VI. Theory

Block 1: Plantation Crops

Unit I: *In-vitro* mass multiplication techniques: *In-vitro* conservation of plantation crops, direct and indirect organogenesis, micro grafting, hardening techniques.

Unit II: *In-vitro* breeding: Production of haploids, somaclones and identification of somaclonal variants, *in-vitro* techniques to overcome fertilization barriers, protoplast culture and fusion, construction, identification and characterization of somatic hybrids and cybrids, wide hybridization, embryo rescue of recalcitrant species. *In-vitro* mutation for biotic and abiotic stresses, disease elimination in crops.

Unit III: Transgenic crops: Recombinant DNA methodology, gene transfer methods, tools, methods, applications of rDNA technology. Role of molecular markers in characterization of transgenic crops, fingerprinting of cultivars, etc., achievements, problems and future thrusts.

Block 2: Spice Crops

Unit I: *In-vitro* mass multiplication techniques: *In-vitro* conservation of spice crops. direct and indirect organogenesis, micro grafting, hardening techniques, production of microrhizomes.

Unit II: *In-vitro* breeding: Production of haploids, somaclones and identification of somaclonal variants, *in-vitro* techniques to overcome fertilization barriers, Protoplast culture and fusion, construction, identification and characterization of somatic hybrids and cybrids, wide hybridization, embryo rescue of recalcitrant species, *in-vitro* mutation for biotic and abiotic stresses, disease elimination in crops.

Unit III: Transgenic crops: Recombinant DNA methodology, gene transfer methods, tools, methods, applications of rDNA technology. Role of molecular markers in characterization of transgenic crops, fingerprinting of cultivars, etc., achievements, problems and future thrusts.

Block 3: Medicinal and Aromatic Crops

Unit I: *In-vitro* mass multiplication techniques: *In-vitro* conservation of medicinal and aromatic crops, direct and indirect organogenesis, micro grafting, hardening techniques, production of microrhizomes.

Unit II: *In-vitro* breeding: Production of haploids, somaclones and identification of somaclonal variants, *in-vitro* techniques to overcome fertilization barriers, Protoplast culture and fusion, construction, identification and characterization of somatic hybrids and cybrids, wide hybridization, embryo rescue of recalcitrant species, *in-vitro* mutation for biotic and abiotic stresses, disease elimination in crops.

Unit III: Transgenic crops: Recombinant DNA methodology, gene transfer methods, tools, methods, applications of rDNA technology. Role of molecular markers in characterization of transgenic crops, finger printing of cultivars, etc., achievements, problems and future thrusts.

Unit IV: *In-vitro* production of secondary metabolites: *In-vitro* production and characterization of secondary metabolites, bioreactors.

Crops

Coconut, Rubber, Oil palm, Coffee, Tea, Cocoa, Black pepper, Cardamom, Turmeric, Ginger, Vanilla, Periwinkle, Rauvolfia, Mint, Cymbopogon grasses, Medicinal coleus, *Ocimum* sp., Aswagandha, Aloe, Safed musli, Stevia

VII. Learning outcome

The learner is expected to be:

- acquainted with the applications of biotechnology in PSMA crops
- able to start modern labs based on biotechnology in PSMA crops

VIII. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Bajaj YPS. Ed. 1987. *Biotechnology in Agriculture and Forestry*. Springer.

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I. Course Title : Abiotic Stress Mangement in Plantation, Spices, Medicinal and Aromatic Crops

II. Course Code : PSM 606

III. Credit Hours : (2+1)

IV. Why this course ?

Global climate is undergoing drastic changes and crops find it difficult to adapt to the changed environments. Abiotic stress due to temperature, water, salts, radiations, nutrients, pollutants, etc. affects the growth, physiology, yield and quality attributes of PSMA crops. This course is designed for the learner to understand the influence of these abiotic stress factors on PSMA crops.

V. Aim of the course

The course aims to impart knowledge on the influence of abiotic stress factors on growth, physiology, yield and quality attributes of PSMA crops along with advanced approaches in the management of these stresses.

The course is organized as follows:

No	Blocks	Units
1	Abiotic Stress	I Temperature and water stress
		II Stress due to soil conditions and salt
		III Pollution stress
		IV Other stresses
2	Climate Change	I Contributing factors
		II Carbon trading
		III Impact of climate change on PSMA crops
3	Climate Resilient Technologies	I Varieties
		II Climate resilient technologies
		III Waste management

VI. Theory

Block 1: Abiotic Stress

Definition, soil conditions (salinity, alkalinity, ion toxicity, fertilizer toxicity, etc.), salt stress

Unit I: Temperature and water stress: Stresses due to water (high and low), temperature (high and low), symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Unit II: Stress due to soil conditions and salts: Alkainity, salinity, iron toxicity, fertilizer toxicity symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Unit III: Pollution stress: Gaseous pollutants and heavy metals, symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Unit IV: Other stresses: Stress due to radiation, wind, nutrients. symptoms, mechanisms governing tolerance, associated physiological and biochemical factors, impact on PSMA crops and produce, changes in phenology and quality.

Block 2: Climate change

Unit I: Contributing factors: Introduction to climate change, factors contributing to climate change, change in temperature, rainfall, humidity, rise in the atmospheric CO_2 levels, tropospheric ozone levels, extreme climatic events.

Unit II: Carbon trading: Global warming, carbon trading, role of green housegases, impact on productivity of PSMA crops. Clean development mechanism.

Unit III: Impact of climate change on PSMA crops: Plantation crops, Spice crops, Medicinal and aromatic crops.

Block 3: Climate resilient technologies

Unit I: Varieties: Plantation crops, Spice crops, Medicinal and aromatic crops.

Unit II: Climate resilient technologies: Plantation crops, Spice crops, Medicinal and aromatic crops.

Unit III: Waste management: Alternate farming systems, Zero waste management, Microbial waste management.

VII. Practical

- Analysis of plant stress factors;
- Relative water content;
- Chlorophyll stability index;
- Plant waxes;
- Stomatal diffusive resistance;
- Transpiration;

- Photosynthetic rates;
- Calculation of water use efficiency and growth rates;
- Identifying abiotic stress symptoms and injuries;
- Use of antitranspirants;
- Managing nutrient stress;
- Stress management by hormones;
- Screening for abiotic stress tolerance;
- Weather data analyses and quantification of climate change;
- Cropping pattern changes due to climate extremities;
- Phenological and quality changes in PSMAs;
- Pesticide residue analysis in PSMAs.

VIII. Learning outcome

The learner is expected to get empowered on

- the impact of abiotic stress on PSMA crop production
- the mitigation measures to be adopted for sustaining PSMA crop production

IX. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Ahmad, Parvaiz, and Prasad MNV. 2012. *Abiotic Stress Responses in Plants Metabolism, Productivity and Sustainability*. Springer.

E- manual on *Advances in Cashew Production Technology*. ICAR- Directorate of Cashew Research, Puttur– 574 202, D.K., Karnataka.

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Jenks MA and Hasegawa PM. 2003. *Plant Abiotic Stress*. Black Well.

Levitt J. 1972. *Response of Plants to Environmental Stresses*. Academic Press.

Manish B. 2018. *Climate resilient agriculture: Adaptation, mitigation strategies*. New India Publishing Agency, New Delhi.

Mussell H and Staples R. 1979. *Stress Physiology in Crop Plants*. Wiley Inter. Science.

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Roy B and AK Basu. 2009. *Abiotic stress tolerance in crop plants*. New India Publ. House.

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www.plantphysiol.org, www.plantsress.com

I. Course Title : Organic Spice and Plantation Crops Production

II. Course Code : PSM 607

III. Credit Hours : (2+1)

IV. Why this course ?

A shift to organic agriculture is happening in different parts of the world. Demand for organic plantation and spice crops is also increasing globally. This course is designed to give comprehensive knowledge on scientific organic farming technology in plantation and spice crops.

V. Aim of the course

To impart knowledge on principles, concepts, techniques and certification procedures of organic farming in spice and plantation crops

The course is organized as follows

No	Blocks	Units
1	Concepts of Organic Farming	I. Importance II. Organic conversion plan III. Organic farming systems
2	Organic Production Technologies	I. Plantation crops II. Major spices III. Minor spices
3	Certification and Quality Control	I. Accreditation II. Organic standards III. Quality control

VI. Theory

Block 1: Concepts of Organic Farming

Unit I: Importance: Principles, perspectives, concepts and components of organic farming, present status of organic farming at national and global level, domestic and global demand for organic products with respect to spice and plantation crops, organic production and export–opportunities and challenges.

Unit II: Organic Conversion Plan: Advanced methods for enhancing soil fertility, soil amendments. Modern methods of composting, vermicomposting, coir pith composting, bio fertilizers, pest and disease management in organic farming; crop rotation in organic horticulture, weed management, botanicals and bio- control agents.

Unit III: Organic Farming Systems: Natural farming, permaculture, biodynamic farming, Zero budget farming, Homa farming, EM technology.

Block 2: Organic Production Technology

Unit I: Plantation crops: Coconut, Coffee, Cocoa, Tea.

Unit II: Major Spices: Black pepper, Cardamom, Ginger, Turmeric, Vanilla.

Unit III: Seed spices: Coriander, Cumin, Fennel, Fenugreek.

Block 3: Certification and Quality Control

Unit I: Accreditation: Accreditation agencies, certification agencies, procedure of certification, types of certification.

Unit II: Organic standards: Domestic and international standards, NPOP, IFOAM, CODEX, HACCP standards.

Unit III: Quality control: Participatory Guarantee System (PGS) in quality control, quality control for organic products.

VII. Practical

- Enrichment of composts;
- Biofertilizers;
- Bio control agents;
- Biodynamic preparations;
- Zero- budget preparations;
- Biopesticides;
- AMF in organic production;
- Waste management techniques;
- Exposure visits to organic fields, certification and marketing centers.

VIII. Learning outcome

The learner is expected to get empowered on

- the organic farming techniques in Spice and Plantation crops
- the organic certification procedures in Spice and Plantation crops

IX. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Dahama AK. 2005. *Organic Farming for Sustainable Agriculture*. 2nd Ed. Agrobios.

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Palaniappan SP and Annadarai K. 2003. *Organic Farming: Theory and Practice*. Scientific Publ.

Panda H. 2013. *The Complete Book on Cashew*. Asia Pacific Business Press Inc.

Panda H. 2016. *The Complete Book on Cultivation and Manufacture of Tea* (2nd Revised Edition). Asia Pacific Business Press Inc.

Parthasarthy VA, Kandiannan V and Srinivasan V. 2008. *Organic Spices. New India* Publ. Agency.

Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2008. *Management of Horticultural Crops*. New India Publ. Agency.

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Shivashankar K. 1997. *Food Security in Harmony with Nature*. 3, IFOAM- RD, ASIA, Scientific Conference. 1-4 Dec., 1997, UAS, Bangalore.

I. Course Title : Marketing and Trade of Plantation, Spices, Medicinal and Aromatic Crops

II. Course Code : PSM 608

III. Credit Hours : (2+1)

IV. Why this course ?

Marketing and trade are two important aspects in the domestic as well as international movement of PSMA crops. Instability in the price structure as well as demand of various plantation and spice crops often puts the farmers and enterpruners at risk. This course is designed to impart in the learner a deeper understanding on marketing and trade in raw materials and value added products of PSMAs crops both at the domestic and international level.

V. Aim of the course

This course is designed to impart in the learner a deeper understanding on marketing and trade in raw materials and value added products of PSMAs crops both at the domestic and international level.

The course is organized as follows

No	Blocks	Units
1	Importance of Marketing and Trade	I. Market opportunities II. Marketing strategies
2	Marketing Channels	I. Market organisations II. Value chain management and total quality management
3	Entrepreneurship Development	I. Decision making II. Price structure

VI. Theory

Block 1: Importance of marketing and trade

Unit I: Market opportunities: Market opportunities and challenges in PSMA crops at the domestic and global level, consumption in India's plantation, herbal and spice and other industries, Demand-supply scenario of PSMAs at the national and international level, Marketing and trade in raw materials and value added products

Unit II: Marketing strategies: Direct and indirect marketing, niche marketing, specialty markets, market intermediaries and their role, market infrastructure needs, marketing efficiency. market organization, planning, promotion, cost control, contract farming

Block 2: Marketing Channels

Unit I: Market organizations: Marketing co-operatives including tribal co-operatives, public private partnerships (PPP), Farmer Producer Companies (FPC) and Farmer Producer Organisations (FPOs).

Unit II: Supply chain management and total quality management: Good transportation procedures, cold storage facilities, State trading, warehousing and other govt. agencies. Role of commodity boards and export promotion councils in marketing and export of PSMA crops

Block 3: Entrepreneurship development

Unit I: Decision making: Risk taking, motivation, importance of planning, monitoring, evaluation and follow up, SWOT analysis, generation, incubation and commercialisation of ideas and innovations. Communication skills, domestic and export market intelligence, export standards. Role of information technology and telecommunication in marketing of PSMAs

Unit II: Price structure: Price analysis and price forecasting in PSMA crops, policies on export, import and re-export of commodities and value added products, guidelines for marketing of organic produce and organic products

VI. Practical

- Study of requirement of various raw materials by the plantation, spice and ayurveda industries;
- Demand supply analysis of various PSMA crops;
- Exposure visit to trading centres, exporters, ware houses, value addition units, etc.;
- Study of FPOs and FPCs in various crops;
- Preparation and evaluation of projects;
- Documentation of case studies.

VII. Learning outcome

The learner is expected to get empowered on

- the marketing and trade oppurtunites and channeles in PSMA crops
- the enterprenureship development and value chain in PSMA crops
- decision support and pricing system in PSMA crops

VIII. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*. CRC Press.

Chinnappa B. 2018. *Economics and marketing of Arecanut in India.* Narendra Publishing House, New Delhi.

CUTS. 2004. *Data base on Medicinal Plants*. CUTS Centre for International Trade, Economics and Environment, Calcutta.

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Holly J and Cheria K. 1998. *The medicinal plant Sector in India*. Medicinal and Aromatic Programme in Asia (MAPPA), New Delhi, India.

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e-Resource

www.nmpb.nic.in

Suggested Journals

Sr. No.	Name of the Journal	ISSN No.
1	*Annals of Horticulture*	0976-4623
2	*Biological Agriculture and Horticulture*	2165-0616
3	*Current Horticulture*	2455-7560
4	*European Journal of Medicinal Plants*	2231-0894
5	*Horticulture Enviornment and Biotechnology*	2211-3460
6	*Indian Coconut Journal*	0970-0579
7	*Indian Horticulture Journal*	2347-3029
8	*Indian Journal of Arecaunt Spices and Medicinal Plant*	0972-2483
9	*Indian Journal of Arid Horticulture*	2249-5258
10	*Indian Journal of Horticulture*	0974-0112
11	*International Journal of Horticulture*	1927-5803
12	*International Journal of Horticulture, Agriculture and Plant Sciences*	2572-3154
13	*International Journal of Innovative Horticulture*	2320-0286
14	*International Journal of Seed Spices*	
15	*International Journal of Tea Science*	0972-544X
16	*Journal of Applied Horticulture*	0972-1045
17	*Journal of Herbs, Spices, and Medicinal Plants*	1540-3580
18	*Journal of Medicinal and Aromatic Plant Sciences*	0253-7125
19	*Journal of Medicinal Food*	1557-7600
20	*Journal of Medicinal Plant Research*	1996-0875
21	*Journal of Medicinal Plant Studies*	2320-3862
22	*Journal of Plantation Crops*	2454-8480
23	*Journal of Spices and Aromatic Crops*	0971-3328
24	*Medicinal Plants: International Journal of Phytomedicines and Related*	0975-4261
25	*Polycyclic Aromatic Compounds*	1040-6638
26	*Progressive Horticulture*	2249-5258
27	*Rubber Science (Natural Rubber Research)*	2524-3993
28	*Spice India*	0970-5805
29	*The Asian Journal of Horticulture*	0973-4767

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Horticultural Sciences
– Post-harvest Management

Preamble

(Post-harvest Managment)

Postharvest Management is an interdisciplinary science and technology applied to horticulture produce after its harvest for its protection, conservation, processing, packaging, distribution, marketing, and utilization to meet the food and nutritional requirements of people. India is the 2nd largest producer of fruits and vegetables in the world. Several studies suggest that around 30–40% of produced fruits and vegetables are lost before they reach final consumer. These losses occur during different stages of harvesting, handling, packaging, transportation, in wholesale and retail markets. Moreover, only 2.5% of the produce is processed, to minimize the losses of fruits, vegetables, flowers, plantation and spice crops and to increase the farmers income there by guaranteeing the national food and nutritional security. Postharvest losses vary greatly among commodities and production areas and seasons. There is a need for man power with specialization in postharvest management to meet and tackle the above demands and to develop an action plan for establishing an effective post harvest research and extension programme to strengthen the link between researchers and extensionists. Looking to the importance of this sector,the Post Harvest Technology (Horticultural Crops), was considered as an independent discipline till the recent past, but it was deleted as independent discipline horticulture since 2009. However, 22 universities have continued department of Post-Harvest Management/ Technology and in some universities the discipline combined with Fruit Science department. The post-harvest agri/ horticulture management of perishable commodities like horticultural crops, which are primarily physiological in nature, is distinctly different than the PHT of the food grains, fish, dairy and meat. It was therefore suggested that an independent discipline of Postharvest Management should be considered in horticulture discipline.

There is a need for post-graduate students to conduct in-depth research on several aspects of postharvest management in order to reduce the losses in quality and quantity and to maintain safety of the produce between harvest and consumption and also to support the farmers and encourage entrepreneurs thereby providing employment opportunities as well as conducting research programmes after obtaining their degrees. They would serve in different universities as teaching faculty and in research stations as scientists and also can serve the nation by creating employment as entrepreneurs. M.Sc. and Ph.D. syllabi in Postharvest Management were drafted through a series of meetings/ workshops conducted at VCSGUUHF, Uttarakhand, BCKV, Mohanpur and IARI, New Delhi.

Courses have been designed emphasising the following thrust areas: Storage methods to extend shelf life and to enhance the nutritional compounds in functional foods, Standardization of processing technologies (drying, canning, freezing, etc.) for extending shelf life, Preserve the phytochemical and nutritional content of fruits and vegetables at every step of the food distribution system, Waste processing and value addition in fruits, Integrating available technologies (bio-, info- and nanotechnology) through a system, Pre and Post-harvest treatments to enhance shelf life, Testing bioactive compounds from fruits and vegetables and their action against pathogens, Safe and minimal processing, Use of robotics for harvesting, packing and handling of individual through bulk items; managing logistics and supply chains effectively and efficiently, Physiological and biochemical systems regulating product deterioration and senescence, Innovations in packaging and storage technology of fresh produce, Active and smart packaging film for food and Postharvest treatment, Studies of reusable/ recyclable packages, Inexpensive and safer ripening systems, Low-cost cooling methods and Sanitation and food safety practices.Besides due importance has been given while designing the course contents towards the national priorities and policies, viz., skill developmet and employment generation, doubling farmers income, nutritional security and minimising food loss/ waste.

Course Title with Credit Load
M.Sc. (Hort.) in Post-Harvest Management

Course Code	Course Title	Credits Hours
PHM 501 *	Postharvest Management of Horticultural Produce	2+1
PHM 502*	Postharvest Physiology and Biochemistry of Perishables	2+1
PHM 503	Packaging and Storage of Fresh Horticultural Produce	1+1
PHM 504	Packaging and Storage of Processed Horticultural Produce	1+1
PHM 505*	Principles and Methods of Fruit And Vegetable Preservation	2+1
PHM 506	Laboratory Techniques in Postharvest Management	1+2
PHM 507*	Processing of Horticultural Produce	2+2
PHM 508	Quality Assurance, Safety and Sensory Evaluation of Fresh and Processed Horticultural Produce	2+1
PHM 509	Functional Foods from Horticultural Produce	2+0
PHM 510	Marketing and Entrepreneurship in Postharvest Horticulture	1+1
	Minor Courses (08 credits)	08
	Supporting Courses (06 credits)	06
	Common compulsory courses (05 credits)	05
PHM 591	Seminar	0+1
PHM 599	Research	0+30
	Total	**70**

*Compulsory among major courses

Course Contents
M.Sc. (Hort.) in Post-harvest Management

I. **Course Title** : **Postharvest Management of Horticultural Produce**
II. **Course Code** : **PHM 501**
III. **Credit Hours** : **(2+1)**

IV. Why this course ?

Fruits and vegetables are perishable crops that suffer great losses both in quantity and quality after harvest. These produce require integrated approach to arrest their spoilage and overcome the present day challenges that assimilates millions of tons annually. Lack of postharvest awareness and absence of sufficient and functioning equipment in the postharvest chain result in serious postharvest losses in developing countries. Clear and comprehensive understanding of postharvest deteriorative factors is necessary to overcome these challenges. Pre and postharvest management such as good cultural practices, use of improved varieties, good handling practices pre and postharvest, temperature and relative humidity management, storage atmosphere management, use of permitted chemicals, design of appropriate packaging materials and storage structures are some of the control measures use in reducing postharvest losses. Hence this customized course

V. Aim of the course

To impart comprehensive knowledge on management of horticultural produce thus extending the post-harvest life of the produce by various treatments.

The course is organized as follows:

No	Blocks	Units
1	Postharvest management of horticultural produce	I Importance and scope II Regulation of ripening III Treatments for extending shelf life IV Handling system and marketing of horticultural crops

VI. Theory

Block 1: Postharvest Management of Horticultural Produce

Unit I: History, Importance and scope of Postharvest technology of horticultural produce. Nature and structure of horticultural produce. Pre and Postharvest losses and their causes.

Unit II: Climacteric and non-climacteric fruits. Regulation of ripening by use of chemicals and growth regulators. Control of sprouting, rooting and discoloration in vegetables.

Unit III: Maturity indices for harvest. Harvesting and harvesting tools. Curing in roots and tubers. Prepackage Operation: Preecooling, washing, sorting, grading of horticultural perishables for local markets and export. Postharvest handling of spices, plantation crops, medicinal and aromatic plants. Equipments for washing, sizing, grading.

Unit IV: Pre and Postharvest treatments for extending storage life/ vase life. VHT, irradiation treatment, skin coating, degreening, etc. Prepackaging, Packaging techniques for local market and export. Standardsand specifications for fresh produce.

Unit V: Postharvest handling system for horticulture crops of regional importance. Principles of transport, modes of transportation, types of vehicles and transit requirements for different horticultural produce. Marketing: Factors influencing marketing of perishable crops, marketing systems and organizations.

VII. Practical

- Study of maturity indices for harvest of fruits, vegetables, spices and plantation crops;
- Protective skin coating with wax emulsion and pre and Postharvest treatment with fungicides, chemicals and growth regulators to extend the shelf life of fruits and vegetables;
- Prepackaging of perishables;
- Extension of vaselife of cut flowers by use of chemicals and growth regulators;
- Control of sprouting of potato and onion by using growth regulators;
- Study of modern harvesting, sorting and grading equipments;
- Study of effect of pre-cooling on shelf-life and quality of fresh fruits, vegetables and flowers;
- Visit to packaging centers;
- Visit to local markets, cooperative organizations, super markets dealing with marketing of Perishables.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentation
- Group Work/ seminars

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Regulation of ripening by use of chemicals and growth regulators
- Pre and Postharvest treatments for extending storage life/ vase life
- Standards and specifications for fresh produce

X. Suggested Reading

Bhattacharjee SK and Dee LC. 2005. *Postharvest technology of flowers and ornamental plants*. Pointer publishers, Jaipur.

Chattopadhyay SK. 2007. *Handling, transportation and storage of fruit and vegetables*. Gene-Tech books, New Delhi.

FAO. 2007. *Handing and Preservation of Fruits and Vegetables by Combined methods for Rural Areas*-Technical Manual. FAO Agr.Ser.Bull., 149.

Kader AA. 1992. *Postharvest technology of horticultural crops*. 2nd ed university of California.

Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Postharvest Biology and Technology of Fruits, Vegetables and Flowers*, Wiley-Blackwell, ISBN: 9780813804088.

Pruthi JS. 2001 (Reprint). *Major spices of India crop management and Postharvest technology*. ICAR, NewDelhi

Stawley J Kays. 1998. *Postharvest physiology of perishable plant products*. CBS publishers.

Sudheer KP, Indira V. 2007. *Postharvest Technology of Horticultural Crops*, Peter K.V. (Ed.), New India Publishing Agency, ISBN 9788189422431.

Sunil Pareek (Ed.) 2016. *Postharvest Ripening Physiology of Crops*, CRC Press, ISBN 9781498703802.

Thompson AK. (Ed.) 2014. *Fruit and Vegetables: Harvesting, Handling and Storage* (Vol. 1 & 2) Blackwell Publishing Ltd, Oxford, UK. ISBN: 9781118654040.

Verma LR and Joshi VK. 2000. *Postharvest Technology of Fruits and Vegetables: Handling, Processing, Fermentation and Waste Management*. Indus Publishing Company, New Delhi, India. ISBN 8173871086.Wills RBH and Golding J. 2016. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*, CABI Publishing, ISBN 9781786391483.

Wills RBH and Golding J. 2017. *Advances in Postharvest Fruit and Vegetable Technology*, CRC Press, ISBN 9781138894051.

Websites:

Horticulture-Post harvest management CSIR-NISTADS http://www.nistads.res.in/indiasnt2008/t6rural/t6rur13.htm

Post harvest technology- MANAGE http://www.manage.gov.in/ftf-itt/prgReports/iihr.pdf

Role of post-harvest management http://www.fao.org/3/y5431e/y5431e02.htm

I. Course Title : Postharvest Physiology and Biochemistry of Perishables

II. Course Code : PHM502

III. Credit Hours : (2+1)

IV. Why this course ?

Immediately after harvesting, vegetables and fruits are subjected to the active processes of degradation. Numerous physiological and biochemical processes continuously change the original composition of the crop until which decrease the shelf life of the produce. Postharvest physiology is the scientific study of the physiology of living plant tissues after picking. It is very much necessary to learn about it as has direct applications to postharvest handling in establishing the storage and transport conditions that prolong shelf life. Hence this customized course.

V. Aim of the course

To impart comprehensive knowledge on physiology of horticultural produce after harvest and to understand different physiological processes like respiration ripening

The course is organized as follows:

No	Blocks	Units
1	Biochemistry of perishable	I. Structure and composition of horticultural produce II Biochemical Changes after harvest

No	Blocks	Units
2	Postharvest physiology of perishables	I Maturity, Ripening and respiration II Respiratory climacteric and transpiration III Factors affecting shelf-life

VI. Theory

Block 1: Biochemistry of perishables

Unit I: Introduction, biochemical structure and composition of fruits, vegetables and ornamentals.

Unit II: Biochemical changes during development and ripening. Structural Deterioration of the Produce-cell wall degradation, change in membrane lipid.: Biosynthesis of ethylene and its regulation. Ethylene action and ripening processes, its perception-action and regulation.

Block 2: Postharvest physiology of perishables

Unit I: Determining maturity and maturity indices. Ripening processes: events of ripening and factors affecting them.

Unit II: Physiology of preharvest and postharvest; factors affecting shelf-life and quality of fruits, vegetables and ornamentals.

Unit III: Respiration: respiratory climacteric, its significance. Transpiration and water stress during postharvest. Postharvest oxidative stress: active oxygen species, AOS generation, physiological effects on horticultural commodity, control of oxidative injury.

VII. Practical

- Determination of physical parameters like specific gravity, fruit firmness, etc.;
- Determination of physiological loss in weight;
- Determination of chemical constituents like sugar, starch, pigments, Vitamin C, acidity during maturation and ripening in fruits/ vegetables;
- Estimation of ethylene evolved from ripening fruits;
- Delay/ Hastening of ripening by ethylene treatments;
- Determination of firmness, TSS, moisture, Titratable acid, sugar, protein, starch, fats, chlorophyll, carotene, anthocyanin, phenols and tannins;
- Measurement of respiration and ethylene evaluation.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations
- Group Work

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand about different factors affecting shelf life
- Processes of respiration and ripening
- Biosynthesis of ethylene and its action on ripening

X. Suggested Reading

Chadha KL and Pal RK. 2015. *Managing postharvest quality and losses in horticultural crops*. Vol-1: General Issues, 1-231p Astral International (P) Ltd., New Delhi

Chadha KL and Pal RK. 2015. *Managing postharvest quality and losses in horticultural crops*. Vol-2: Fruit Crops, 253-561p Astral International (P) Ltd., New Delhi

Chadha KL and Pal RK. (2015) *Managing postharvest quality and losses in horticultural crops*. Vol-3: Vegetables, Flowers and Plantation Crops, 581-727p Astral International (P) Ltd., New Delhi

Hodges DM. 2003. *Postharvest Oxidative Stress in Horticultural Crops*, 1st Edition, ISBN 9781560229636

Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Postharvest Biology and Technology of Fruits, Vegetables and Flowers*, Wiley-Blackwell, ISBN: 9780813804088.

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Thompson AK. 1995. *Post harvest Technology of fruits and vegetables*. Blackwell Sciences

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Wills RBH and Golding J. 2017. *Advances in Postharvest Fruit and Vegetable Technology*, CRC Press, ISBN 9781138894051.

Wills RBH and Golding J. 2016. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*, CABI Publishing, ISBN 9781786391483.

Websites

Food and Agriculture Organization http://www.fao.org/home/en/

Respiration in plants http://ncert.nic.in/ncerts/l/kebo114.pdf

Ethylene biosynthesis and its response http://www.biologydiscussion.com/plants/hormones-plants/ethylene-biosynthesis-and-its-responses-plant-hormones/25986

I. Course Title : Packaging and Storage Offresh Horticultural Produce

II. Course Code : PHM 503

III. Credit Hours : (1+1)

IV. Why this course ?

Being a potential source of minerals, vitamins and proteins and carbohydrates, horticultural commodities play an important role in the health and nutritional security of the people. Proper packaging and storage will utilize market surplus during glut season and thus give boost to the food industry. Horticultural produce is highly perishable particularly under tropical conditions of India. The spoilage of these commodities can be reduced to a large extent by this storage technology. Hence this customized course

V. Aim of the course

To acquaint with the different storage systems and packaging systems for perishable horticultural produce.

The course is organized as follows:

No	Blocks	Units
1	Storage systems	I. Importance of storage II. Different methods of storage III. Modified methods of storage

No.	Block	Unit
2	Packaging	I. Importance of packaging and packaging methods II. New technologies in packaging

VI. Theory

Block 1: Storage Systems

Unit I: Importance of storage of horticultural produce, present status and future scope. Principles and methods of storage – field storage structures and designs for bulk storage of horticultural produce- onion and potato, etc. Evaporative cool chambers. Physiological changes during storage.

Unit II: Refrigerated storage – principles of refrigeration, types of refrigerants, refrigeration equipments. Cold storage rooms – Calculation of refrigeration load. Storage requirements of different fruits, vegetables, flowers. Storage disorder symptoms and control.

Unit III: Controlled or modified atmosphere (CA/MA) storage – principles, uses, structures and equipments, methods and requirements. Effect of CA storage on the physiology of stored produce. Hypobaric storage-principle, uses, and requirements. Storage disorders.

Block 2: Packaging

Unit I: Importance of packaging of fresh and processed horticultural produce, present status and future scope. Gaps in packaging concepts. Packaging requirements of fresh horticultural produce. Packaging patterns and methods. Food packaging systems: Different forms of packaging such as rigid, semi-rigid, flexible forms. Traditional, improved and specialized packages. Paper based packages: corrugated fibre board boxes – raw material and types of boxes. Flexible packaging materials – types and their properties. Consumer and intermediate flexible bulk containers. Testing of flexible packaging material. Barrier properties of packaging materials.

Unit 2: New technology in packaging – stretch wrapping system, vacuum packaging, gas packaging, controlled atmosphere (active and intelligent) packaging, vibra packaging, skin packaging, shrink packaging, form-fill-seal packaging, Packaging machines.Quality control and safety aspects of packaging materials.

VII. Practical

- Study of special storage structures for bulk storage of onion/ potato, etc.;
- Study of storage behavior of different fruits and vegetables in zero energy cool chamber;
- Determination of refrigeration requirements (capacity) for given quantity of fruits and vegetables;
- Study of storage behaviour of different fruits and vegetables in cold room;
- Study of chilling injury and storage disorders;
- Study of shelf-life of fruits and vegetables in modified atmosphere packaging. Visit

to special storage structures, cold storage units. Study of types of packaging materials, types of plastic films and their properties;
- Determination of water vapour transmission rate (WVTR) and gas transmission rate (GTR) of packaging material;
- Applications of packaging material for fresh fruits and vegetables, beverages, spice products;
- Determination of shelf-life of fresh products in different types of packages;
- Study of packaging machines – vacuum packaging machine, shrink wrapping machine, double seamer, etc. Visit to packaging unit.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations
- Group Work/ seminars

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:
- Importance of storage of horticultural produce
- Different methods of storage
- Importance of packaging for fresh horticultural produce
- Different methods of packaging

X. Suggested Reading

Ahvenainen R. 2003. Novel Food Packaging Techniques, CRC Press, ISBN 0849317894.
Ahvenainen R. 2001. *Novel Food Packaging Techniques*. CRC.
Burg SP (Ed.). 2004. *Postharvest physiology and hypobaric storage of fresh produce*, CABI Publishing, ISBN 0851998011.
Chattopadhya SK. 2007. *Handling, transportation and storage of fruits and vegetables*. Gene-Tech books, New Delhi.
Chandra GopalaRao. 2015. *Engineering for Storage of Fruits and Vegetables*; Academic Press, 1st Edition.
Coles R, McDowell D and Kirwan MJ. (Eds.). 2003. *Food Packaging Technology*, Blackwell Publishing, ISBN 1841272213.
Mahadevaiah M and Gowramma RV. 1996. *Food packaging materials*. Tata McGraw Hill.
Painy FA. 1992. *A handbook of food packaging*. Blackie Academic.
Pantastico B. 1975. Postharvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables. AVI Publ.
Robertson GL. (Ed.). 2010. Food packaging and shelf life: a practical guide CRC Press, ISBN 9781420078442.
Thompson AK. 2010. *Controlled atmosphere storage of fruits and vegetables* (2nd Edition), CABI International, ISBN 9781845936464.
Wilson CL. (Ed.). 2007. *Intelligent and active packaging for fruits and vegetables*, CRC Press, ISBN 9780849391668.

Websites

Storage practices and structures UCANR http://ucanr.edu/datastoreFiles/234-1303.pdf
Low cost storage technologies for preservation-IARI http://www.iari.res.in/download/pdf/story4_eng.pdf
https://energypedia.info/wiki/Cold_Storage_of_Agricultural_Products

I. Course Title : Packaging of Processed Horticultural Produce

II. Course Code : PHM 504

III. Credit Hours : (1+1)

IV. Why this course ?

Horticulture industry is dominated by market interaction in terms processing and their packaging. Much of the total cost of produce is determined by nature of packaging and packaging material used. Packaging cost sometimes exceed the raw material cost, depending on the nature of the produce, time and period. This course helps in understanding the packaging interaction with produce, environment and time. And it also helps to take informed decision on package requirement for horticulture produce.

V. Aim of the course

To acquaint with the different and packaging systems for processed horticultural produce.

The course is organized as follows:

No	Blocks	Units
1	Packaging principles and functions	Functions of packaging Basic principles of packaging materials Manufacture of packaging materials Types of packaging materials Testing of packaging

VI. Theory

Block 1: Packaging principles and functions

Unit I: Functions of packaging; Type of packaging materials; Selection of packaging material for different foods; Selective properties of packaging film; Methods of packaging and packaging equipment.

Unit II: Mechanical strength of different packaging materials; Printing of packages; Barcodes and other marking; Interactions between packaging material and foods; Environmental and cost consideration in selecting packaging materials.

Unit III: Manufacture of packaging materials; Potential of biocomposite materials for food packaging; Packaging regulations; Packaging and food preservation; Disposal of packaging materials.

Unit IV: Metal cans: types, fabrication, lacquering and tin quality. Double seaming technology – defects and causes. Glass containers – types; testing quality – thermal shock resistance, thermal shock breakage, impact breakage.

Unit V: Testing of packaging; Rigid and semi rigid containers; Flexible containers; Sealing

Equipment. Labeling; Aseptic and shrink packaging; Secondary and transport packaging. Different packaging systems for dehydrated foods, frozen foods, dairy foods, fresh fruits and vegetables.

VII. Practical

- Testing of packaging material: compression strength/drop test/thermal shock test/ seam evaluation/ seam defects;
- Determination of shelf-life of processed products in different types of packages;
- Study of packaging machines – vacuum packaging machine, shrink wrapping machine, double seamer, etc.;
- Visit to packaging units.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations
- Group Discussions

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Importance of packaging for processed horticultural produce
- Different methods of packaging, methods and their applications in food industry.

X. Suggested Reading

Ahvenainen R. 2001. *Novel Food Packaging Techniques*.CRC

Ahvenainen R. 2003. *Novel Food Packaging Techniques*, CRC Press, ISBN 0849317894.

Coles R, McDowell D and Kirwan MJ. (Eds.) 2003. *Food Packaging Technology*, Blackwell Publishing, ISBN 1841272213.

Joseph H Hotchkiss. 1987. *Food and Packaging Interactions*, (ACS symposium series -365, April 5-10, 1987. American Chemical Society, Washington DC. 1988)

Mahadevaiah M and Gowramma RV. 1996. *Food packaging materials*. Tata McGraw Hill.

Painy FA. 1992. A handbook of food packaging. Blackie Academic.

Robertson G. L. Ed. 2010. *Food packaging and shelf life: a practical guide CRC Press*, ISBN 9781420078442.

Thompson AK. 2010. *Controlled Atmosphere Storage of Fruits and Vegetables*, CABI Publishing; 2nd revised edition.

Wilson CL. (Ed.). 2007. *Intelligent and active packaging for fruits and vegetables*, CRC Press, ISBN 9780849391668.

I. Course Title : Principles and Methods of Fruit and Vegetable Preservation

II. Course Code : PHM 505

III. Credit Hours : (2+1)

IV. Why this course ?

The fruits and vegetables are comparative higher value than cereals and more perishables. Losses in the fruits and vegetables are high and chances to reduce the waste and enhancing the employability through post-harvest processing are more. The processing includes pre-processing of fruits and vegetables before these are fit to final conversation into processed foods. The food preservation and processing industry has now become of a necessity than being a luxury. It has an important role in conservation and better utilization of fruits and vegetables. In order to avoid the glut and utilize the surplus during the season, it is necessary to employ modern methods to extend storage life for better distribution and also processing techniques to preserve them for utilization in the off season on both large scale and small scale. Hence this customized course.

V. Aim of the course

Understanding spoilage, underlying principles and methods of processing of fruits and vegetables.

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand Principles and different methods of preservation
- Principal spoilage organisms, food poisoning and their control measures
- Canning of fruits and vegetables
- Processing equipments and layout of processing industry

VII. Theory

Block 1: Principles and Methods of Fruit and Vegetable Processing

Unit I: Introduction, Historical development in food processing, type of food and causes for food spoilage. Basic principles of fruits and vegetables processing;

Unit II: Thermal processing, pH classification of foods, heat resistance of microorganism; Heat resistance of enzymes in foods, Spoilage of thermal processed food; Containers – canning, rigid tin plates and cans, aluminium cans, glass containers – types; flexible packaging materials, Composite can, specification, corrosion of cans, heat penetration into containers and methods for determination of process time.

Unit III: Effects of low temperature on fresh commodities and prepared product. Freezing preservation, freezing points of foods, slow and quick freezing, Cryogenic freezing and frozen food storage. Drying and dehydration, sun drying solar dehydration, mechanical drying types of driers, osmotic dehydration.

Unit IV: Food fermentation – alcoholic, acetic and lactic fermentation. Pickling and curing; Effect of salt on food preservation, types of salt cured products. Traditional and new products; chemical preservation, SO2, benzoic acid, sorbic acid, antioxidants and antibiotics, newer preservatives. Preservation by controlling water activity – high sugar products, intermediate moisture food, food concentration.

Unit V: Food irradiation, principles, types and sources of radiation, mode of action of ionizing radiation; radiation effect on food constituents and regulation.

VII. Practical

- List and cost of equipment, utensils, and additives required for small scale processing industry;
- Chemical analysis for nutritive value of fresh and processed fruits and vegetables;

- Preparation and preservation of fruit based beverages and blended products from fruits and vegetables;
- Evaluation of pectin grade; preparation and quality evaluation of fruit jam;
- Preparation of papain;
- Blanching and its effects on enzyme;
- Preparation of dehydrated vegetables;
- Study of different types of spoilages in fresh as well as processed horticultural produce;
- Study of biochemical changes and enzymes associated with spoilage;
- Sensory evaluation of fresh and processed fruits and vegetables;
- Visit to processing units.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Exposure visits
- Student presentation
- Group Work

IX. Suggested Reading

Barret DM, Somogyi LP and Ramaswamy H. Eds. 2005. *Processing Fruits: Science and Technology* (2nd Edition), CRC Press, ISBN 9780849314780.

FAO. 2007. *Handling and Preservation of Fruits and Vegetables by Combined Methods for Rural Areas- Technical Manual*. FAO Agricultural Services Bulletin 149.

Fellows PJ. 2009. Food Processing Technology: Principles and Practice (3rd Edition), Woodhead Publishing, ISBN 9781845692162.

Lal G, Siddappa GS and Tandon GL. 1998. Preservation of Fruits and Vegetables. ICAR, ISBN 9788171640904.

Ramaswamy H and Marcotte M. 2006. *Food Processing: Principles andApplications*. Taylor & Francis.

Salunkhe DK and Kadam SS. 1995. Handbook of Fruit Science and Technology:Production, Composition and Processing. Marcel Dekker.

Srivastava RP and Kumar S. 2014. *Fruit and Vegetable Preservation: Principles and Practices* (3rd Edition), CBS Publishing, ISBN 9788123924373.

Verma LR and Joshi VK. 2000. *Postharvest Technology of Fruits and Vegetables: Handling, Processing, Fermentation and Waste Management*. Indus Publishing Company, New Delhi, India. ISBN 8173871086.

Websites

http://agriinfo.in/default.aspx?page=topic&superid=2&topicid=2065
http://www.fao.org/docrep/x0209e/x0209e02.htm
http://www.cstaricalcutta.gov.in/images/CTS%20Fruits_and_Vegetables%20NSQF.pdf

I. Course Title : Laboratory Techniques in Postharvest Horticulture

II. Course Code : PHM 506

III. Credit Hours : (1+2)

IV. Why this course ?

To familiarize with the conventional analysis of raw and processed food products of all commodity technologies used for routine quality control in food industry, and their role on nutritional labeling. To develop an understanding and methodologies of instrumental techniques in food analysis used for objective methods of food quality parameters.

V. Aim of the course

To familiarise with advances in instrumentation and Postharvest management

VI. Theory

Block 1: Laboratory Techniques in Postharvest Management

Unit I: Rheological techniques and instrumentation used in food industry. Analysis of food additives like food colour, antioxidants, emulsifier, etc.

Unit II: Analysis of pesticide residues, metallic contaminants, aflatoxin. Analysis of food flavours.

Unit III: Quality analysis of processed fruits and vegetables, coffee, tea and spices. Identification and enumeration of microbial contaminants.

Unit IV: Principles of chromatography (GC, GCMS, HPLC, LCMS), spectrophotometry (Atomic absorption spectrophotometer, ICAP spectrophotometer), ICP-MS, ICPOES, NMR, ESR, amino acid analyser, flame photometry, electrophoresis.

Unit V: Colour measurement in foods, IRGA, Radio-isotopic techniques. Non destructive quality evaluation (NDQE)- E-nose, E-tongue, machine vision. electrophoresis.

VII. Practical

- Sample preparation for quality analysis. Energy calculation, sample calculations;
- Texture analysis, Rheology of different foods;
- Instrumental colour analysis;
- Sensory evaluation and microbiological examinations of fresh and processed products;
- Estimation of tannin/ phytic acid by spectrometric method;
- Moisture and fat analysis by NIR spectroscopy;
- Separation and identification of sugars in fruit juices;
- Separation and identification of carotenoids by column chromatography;
- Estimation of respiration in fruits and vegetables;
- Flavour profile in essential oils using GC;
- Identification and determination of organic acids by HPLC;
- Capsaicin content and Scoville Heat Units in chillies;
- Heavy metal analysis using atomic absorption spectrometry;
- Residue analysis.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Techniques and instrumentation used in food industry
- Analysis of pesticide residues
- Quality analysis of processed fruits and vegetables

- Principles of chromatography and Spectrophotometry
- Non-destructive quality evaluation

X. Suggested Reading

Lundanes E., Reubsaet L and Greibrokk T. 2013. *Chromatography: Basic Principles, Sample Preparations and Related Methods*, ISBN-13: 978-3527336203, Wiley VCH

Mark F Vitha. 2016. *Chromatography: Principles and Instrumentation*. John Wiley & Sons, ISBN 9781119270881

Suzanne NS. 2010. *Introduction to Food Analysis*, ISBN 978-1-4419-1478-1, Springer.

Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, Tata McGraw-Hill ISBN 9780074518519.

Semih Otles (Ed). 2016. *Methods of Analysis of Food Components and Additives* (*Chemical and Functional Properties of Food Components*) CRC Press, ISBN-13: 978-1138199149,

I. Course Title : Processing of Horticultural Produce

II. Course Code : PHM 507

III. Credit Hours : (2+2)

IV. Why this course ?

Postharvest system deals with ensuring the delivery of a crop from the time and place of harvest to the time and place of consumption, with minimum loss, maximum efficiency and returns to all concerned including grower, processors and consumer. The term 'system' represents a dynamic, complex aggregate of locally interconnected functions or operations within a particular sphere of activity. While, the term pipeline of operations refers to the functional succession of various operations but tends to ignore their complex interactions. Primary processing processing operations include washing/ cleaning,sorting, grading, dehulling, pounding, grinding, packaging, soaking, winnowing, drying, sieving, whitening and milling and secondary operations include mixing, cooking, drying, frying, moulding, cutting, extrusion product preparation.

V. Aim of the course

This course gives an overview of status of fruit and vegetable processing in the country, objectives and importance of preservation, important constraints and different unit operations processing industry which helps in expansion of industry and scope for further growth in this sector.

This course is organized as follows:

No	Blocks	Units
1	Importance and Thermal processes	I Scope and Importance II Thermal processes III Evaporation
2.	Processing equipment and enzyme kinetics	I Processing equipment and facilities II Enzyme kinetics

VI. Theory

Block 1: Importance and Thermal processes

Unit I: Processing unit- layout and establishment, processing tools. Quality requirements of raw materials for processing, preparation of raw material, primary processing: grading, sorting, cleaning, washing, peeling, slicing and blanching; minimal processing.

Unit II: Preparation of various processed products from fruits and vegetables, flowers; role of sugar and pectin in processed products. Freezing of fruits and vegetables. Containers, equipment and technologies in canning.

Unit III: Juice extractions, clarification and preservation, recent advances in juice processing technology, application of membrane technology in processing of juices, preparation of fruit beverages and juice concentrate. Sensory evaluation.

Block 2: Processing equipment and enzyme kinetics

Unit I: Dehydration of fruits and vegetables using various drying technologies and equipment, solar drying and dehydration, packaging technique for processed products.

Unit II: Quality assurance and storage system for processed products. Nutritive value of raw and processed products, plant sanitation and waste disposal. Types of horticultural and vegetables wastes and their uses, utilization of by- products from fruits and vegetables processing industries.

VII. Practical

- Handling of harvesting equipments;
- Determination of physical and thermal properties of horticultural commodities;
- Thermal process calculations;
- Particle size analysis, Storage structure design;
- Numerical problems in freezing, drying, conveying and calculations pertaining to texture and Rheology;
- Handling of heating equipment, pulper, juice extractor, deaerator, juice filters;
- Processing industries waste treatment;
- Working of a canning unit;
- Visit to commercial processing units and storage units.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentations

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Unit operations of processing
- Planning for domestic as well as commercial storage and processing facilities
- Kinetics of growth and enzyme reaction

X. Suggested Reading

Karel M and Lund DB. 2003. *Physical Principles of Food Preservation* (2nd Edition), CRC Press, ISBN 9780824740634.

Paul Singh R and Heldman DR. 2009. *Introduction to Food Engineering* (4th Edition), Academic Press, ISBN 9780123709004.

Rao DG. 2010. *Fundamentals of Food Engineering*, PHI Learning Pvt. Ltd., ISBN 9788120338715.

Ratti C. 2008. *Advances in Food Dehydration*, CRC Press, ISBN 9781420052527.
Toledo RT. 2007. *Fundamentals of Food Process Engineering* (3rd Edition), Springer, ISBN 9780387290195.
Smith PG. 2011. *Introduction to Food Process Engineering*, Springer, ISBN 9781441976611.

I. Course Title : Quality Assurance, Safety and Sensory Evaluation of Fresh and Processed Horticultural Produce

II. Course Code : PHM 508

III. Credit Hours : (2+1)

IV. Why this course ?

The quality of fresh horticultural commodities is a combination of characteristics, attributes, and properties that give the commodity value for food (fruits and vegetables) and enjoyment (ornamentals). Producers are concerned that their commodities have good appearance and few visual defects, but for them a useful cultivar must score high on yield, disease resistance, ease of harvest, and shipping quality. To receivers and market distributors, appearance quality is most important; they are also keenly interested in firmness and long storage life. Although consumers buy on the basis of appearance and feel, their satisfaction and repeat purchases are dependent upon good edible quality. Assurance of safety of the products sold is extremely important to the consumers. Hence this customized course.

V. Aim of the course

To understand the quality and safety management system and the process of sensory analysis for horticultural products

This course is organized as follows:

No	Blocks	Units
1	Quality Assurance	I Concept of quality
		II Food laws and regulations
2	Safety	I Food safety
		II Quality management
3.	Sensory Evaluation	I Introduction to sensory evaluation
		II Methods of sensory evaluation

VI. Theory

Block 1: Quality Assurance

Unit I: Concept of quality: Quality attributes- physical, chemical, nutritional, microbial, and sensory; their measurement and evaluation. Concepts of quality management: Objectives, importance and functions of quality control; Quality management systems in India; Sampling procedures and plans.

Unit II: Food laws and regulations in India, Quality management standards, ISO,BIS, PFA, AGMARK and QMS standards, quality system components and their requirements.

Block 2: Safety

Unit I: Food safety and standards act (FSSA,2006); Strategies for compliance with international agri-food standards; Export specification and guidelines by APEDA. Hazard analysis and critical control points (HACCP), design and implementation of an HACCP system, steps in the risk management process. Traceability in food supply chains.

Unit II: Organic Certification, GAP, GMP, TQM. Indian and International quality systems and standard like, Codex Alimentarius, ISO, etc. Consumer perception of safety; Ethics in food safety.

Block 3: Sensory Evaluation

Unit I: Introduction to sensory analysis; general testing conditions, Requirements of sensory laboratory; organizing sensory evaluation programme. Selection of sensory panellists; Factors influencing sensory measurements; Sensory quality parameters -Size and shape, texture, aroma, taste, colour and gloss; Detection, threshold and dilution tests. Different tests for sensory evaluation– discrimination, descriptive, affective; Flavour profile and tests; Ranking tests.

Unit II: Methods of sensory evaluation of different food products. Designing of experiments. Handling and interpretation of Data. Role of sensory evaluation in product optimization. Relationship between objective and subjective methods.Sensory analysis for consumer evaluation. Computer-aided sensory evaluation of food and beverage.

VII. Practical

- Analysis for TSS, pH, acidity, sugars, pectic substances, minerals, vitamin C, carotene, alcohol, benzoic acid and SO_2 contents, yeast and microbial examination in processed products;
- Demonstration of measurement of vacuum/ pressure, head space, filled weight, drained weight, cut-out analysis and chemical additives;
- Moisture content, rehydration ratio and enzymatic/ non-enzymatic browning in dehydrated products;
- Analysis of spices for quality parameters. Evaluation of processed products according to FSSAI specification;
- Selection and training of sensory panel;
- Identification of basic taste, odour, texture and colour;
- Detection and threshold tests; Ranking tests for taste, aroma, colour and texture; Sensory evaluation of various horticultural processed products using different scales, score cards and tests, Hedonic testing;
- Estimation of color and texture; optimising a product by sensory analysis;
- Studying relationship between objective and subjective methods.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Exposure visits
- Student presentation

IX. Learning outcome

After successful completion of this course, the students are expected to be able to Understand:

- Concepts of quality management
- Food laws and regulation in India

- Export specification and guidelines by APEDA
- Consumer perception of safety and Ethics in food safety

X. Suggested Reading

Amerine MA, Pangborn RM and Rosslos EB. 1965. Principles of Sensory Evaluation of Food. Academic Press.

Curtis PA. 2005. *Guide to Food Laws and Regulations*, Wiley-Blackwell, ISBN 9780813819464.DGHS *Manual 8: Manual of Methods of Analysis of Foods-Food Additives*.

Curtis PA. 2005. *Guide to Food Laws and Regulations*, Wiley-Blackwell, ISBN 9780813819464.

Early R. 1995. *Guide to Quality Management Systems for the Food Industry*, Springer, ISBN 9781461358879.

Kemp SE, Hollowood T and Hort J. 2009. *Sensory Evaluation: A Practical Handbook*, Wiley-Blackwell Publisher, ISBN 9781405162104.

Krammer A and Twigg BA. 1973. Quality Control in Food Industry.Vol.I, II.AVI Publ.

Lawless, Harry T, Heymann and Hildegarde. 2010. Sensory Evaluation of Food: Principles and Practices, Springer, ISBN 9781441964885.

Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, Tata McGraw-Hill ISBN 9780074518519.

Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*, Tata McGraw-Hill, ISBN 9780074518519.

The Food Safety and Standards Act, 2006 along with Rules & Regulations 2011, Commercial Law Publishers (India) Pvt. Ltd.

Websites

https://en.wikipedia.org/wiki/Sensory_analysis
https://link.springer.com/chapter/10.1007/978-1-4757-5112-3_5
https://www.foodqualityandsafety.com/

I. Course Title : Functional Foods from Horticultural Produce

II. Course Code : PHM 509

III. Credit Hours : (2+0)

IV. Why this course ?

Functional foods are foods that have a potentially positive effect on health beyond basic nutrition. This course examines the rapidly growing field of functional foods in the prevention and management of chronic and infectious diseases. It attempts to provide a unified and systematic account of functional foods by illustrating the connections among the different disciplines needed to understand foods and nutrients, mainly: food science, nutrition, pharmacology, toxicology and manufacturing technology. Advances within and among all these fields are critical for the successful development and application of functional foods

V. Aim of the course

To familiarise with functional foods from horticultural produce

This course is organized as follows:

No	Blocks	Units
1	Functional food and importance	I Introduction, Sources and classification
		II Functional Ingredients
2.	Bioactive Compounds	I Introduction and classes of bioactive compounds
		II Mechanism of Neuroprotection

No	Blocks	Units
3.	Neutraceuticals	1 Introduction, classification, role and health benefits

VI. Theory

Block 1: Functional food and importance

Unit I: Functional foods- Introduction, definition, history; Importance, relevance and need of functional foods. Sources and classification of functional foods.Importance of horticultural produce as functional foods. Functional foods derived from fruits, vegetables, medicinal and aromatics.

Unit II: Functional ingredients and their properties. Therapeutic potential and effects of horticultural produce; Herbs, herbal teas, oils, etc. in the prevention and treatment of various diseases. Effect of preservation and processing on functional properties of horticulture produce.

Block 2: Bioactive Compounds

Unit I: Introduction, Classes of bioactive compounds present in fruits and vegetables. Polyphenols: Phenolic acid, Stilbenes, Flavonoids, Lignin, Coumarin, Tannin, etc. –their chemistry, source, bioavailability, interaction in food systems; changes during storage and processing. Alkaloids; Nitrogen Containing Compounds; Sulphur compounds; phytosterols; carotenoids; dietary fibres, etc.–their chemistry, source, bioavailability, interaction in food systems; changes during storage and processing.

Unit II: Mechanism of neuroprotection by bioactive compounds. Techniques of Extraction, purification and concentration of bioactive compounds from fruits and vegetables.Bioactive compound and health benefits Incorporation of bioactive compounds in foods.

Block 3: Neutraceuticals

Unit I: Nutraceuticals- Introduction, classification of nutraceuticals, dietary supplements, fortified foods, functional foods and phytonutraceuticals. Role of medicinal and aromatic plants in nutraceutical industry. Health benefits of phytoneutraceuticals.

VII. Teaching Methods/ Activities

1. Lectures
2. Assignment (Reading/ Writing)
3. Exposure visits
4. Student presentation

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Importance of functional foods
- Functional ingredients and their properties
- Classes of bioactive compounds present in fruits and vegetables
- Mechanism of neuroprotection by bioactive compounds
- Importance of Nutraceuticals

IX. Suggested Reading

Rosa LA, Alvarez-Parrilla E and Gonzalez-Aguilar GA. 2009. *Fruit and Vegetable Phytochemicals: Chemistry, Nutritional Value and Stability*, Wiley-Blackwell, ISBN 9780813803203.

Senrawat R, Khan KA, Goyal MR and Paul PK. 2018. *Technological Interventions in the Processing of Fruits and Vegetables*, Apple Academic Press, ISBN 9781771885867.

Vattem DA. 2016. *Functional Foods, Nutraceuticals and Natural Products: Concepts and Applications*. DEStech Publications, Inc, ISBN 978 1 60595 101 0.

Watson RR and Preedy V. 2009. *Bioactive Foods in Promoting Health: Fruits and Vegetables* (1st Edition), Academic Press, ISBN 9780123746283

I. Course Title : Marketing and Entrepreneurship in Post Harvest Horticulture

II. Course Code : PHM 510

III. Credit Hours : (1+1)

IV. Why this course ?

To develop marketing strategies and equip individuals to start their own food service.To develop Techniques for the development of entrepreneurial skills, positive self image and locus of control.

V. Aim of the course

To understand the market channel and appraise entrepreneurship opportunity in postharvest operations.

This course is organized as follows:

No	Blocks	Units
1	Marketing and entrepreneurship in processing industry	I Entrepreneurship II Business Plan III MSME Enterprise IV Marketing V Institutional supports

VI. Theory

Unit I: Entrepreneurship – Concept, need for entrepreneurship – Types of entrepreneurs -entrepreneurial opportunities in horticultural processing sector-Government schemes and incentives for promotion of entrepreneurship in processing sector.

Unit II: Writing Business Plan- Business Plan Format for Small and micro Enterprises-Generation, incubation and commercialization of business ideas – Environment scanning and opportunity identification.

Unit III: Steps in establishment of MSME Enterprise – Planning of an enterprise – Formulation and project report-Meaning – Importance Components and preparation.-Government Formalities and Procedures.

Unit IV: Marketing potential of processed products at domestic and international level-Marketing management-Marketing functions, market information and market research-Problems in marketing of processed products-Demand and supply analysis of important processed products-

Marketing channels – Marketing strategy (product strategy and pricing strategy)- Supply chain management – Meaning, importance, advantages, supply chain management of important processed products.

Unit V: Institutional support to Entrepreneurship Role of Directorate of Industries, District Industries, Centres (DICs), Industrial Development Corporation (IDC), State Financial corporation (SFCs), Commercial banks Small Scale Industries Development Corporations (SSIDCs), Khadi and village Industries Commission (KVIC), National Small Industries Corporation (NSIC), Small Industries Development Bank of India (SIDBI).

VII. Practical

- Consumer Behaviour towards Processed Foods;
- An Empirical Test-Carrying out the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of successful Enterprises;
- Constraints in setting up of horti based industries;
- Field visits to study any one of the Local Financial Institutions to study the MSME Policies;
- Preparation of business plan and proposal writing-Project evaluation techniques;
- Discounted and undiscounted techniques;
- Case studies of successful entrepreneurs.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/Writing)
- Exposure visits
- Student presentation

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Concept of entrepreneurship
- Writing Business Plan
- Steps in establishment of MSME Enterprise
- Marketing management
- Institutional support to Entrepreneurship

X. Suggested Reading

Adhikary MM. 2014. *Enterprise and Entrepreneurship for Agri-Business Management and Planning*. Daya Publishing House. New Delhi

Bhaskaran S. 2014. *Entrepreneurship Development and Management*. Aman Publishing House, Meerut.

Choudhury M and Barua N. 2014. *Marketing of Processed Fruit and Vegetable*. Daya Publishing House. New Delhi.

Gaur SC. 2012. *Handbook of Agro Food Processing and Marketing*. Agrobios. Jodhpur

Kadam MM and Bishe RN. 2018. *Textbook on Agricultural Entrepreneurship*. Narendra publishing house. New Delhi.

Sudheer KP and Indira V. 2018. *Entrepreneurship and Skill Development in Horticultural Processing*. New India Publishing Agency. New Delhi.

Sudheer KP and Indira V. 2018. *Entrepreneurship Development in Food Processing*. New India Publishing Agency. New Delhi.

Course Title with Credit Load
Ph.D. (Hort.) in Post-harvest Management

Course Code	Course Title	Credit Hours
PHM 601**	Ripening and Senescence of Fruits and Vegetables	1+1
PHM 602**	Recent Trends in Food Preservation	1+1
PHM 603	Management and Utilization of Horticultural Processing Waste	3+0
PHM604**	Supply Chain Management of Perishables	2+0
PHM 605	Export Oriented Horticulture	1+0
PHM 606	Food Additives	1+1
PHM 607	Advances in Processing of Plantation, Spices, Medicinal and Aromatic Plants	3+0
PHM 608	Value Addition in Ornamental Crops	1+1
	Minor courses	06
	Supporting courses	05
PHM 691	Seminar I	0+1
PHM 692	Seminar II	0+1
PHM 699	Research	0+75
	Total	**100**

*Compulsory among major courses

Course Contents
Ph.D. (Hort.) in Post-harvest Management

I. **Course Title** : **Ripening and Senescence of Fruits and Vegetables**

II. **Course Code** : **PHM 601**

III. **Credit Hours** : **(1+1)**

IV. **Why this course ?**

Fleshy fruit experiences profound physiological, biochemical, and structural modifications during ripening to facilitate seed dispersal and to become attractive and nutritious for human consumption. The metabolic networks regulating fruit ripening are very complex, and ethylene appears to be a key factor acting in concert with other environmental signals and endogenous factors. The classical distinction between climacteric and nonclimacteric ripening is now questionable, as different patterns of synthesis and sensitivity to ethylene may operate in the ripening of different fruits. In recent years, much progress has been done in the characterization of the main biochemical pathways implicated in the different ripening-associated processes and in the identification of key genes controlling these events. This course highlights current understanding and advances in the regulation of fruit ripening and key metabolic pathways associated with the different ripening-related processes, with emphasis on their impact on fruit quality.

V. **Aim of the course**

To impart knowledge about physiological and molecular changes during senescence and ripening.

VI. **Theory**

Unit I: Environmental factors influencing senescence, ripening and post harvest life of fruits, flowers and vegetables.

Unit II: Molecular mechanism of senescence and ageing.Physiological, biochemical and molecular aspects of senescence and fruit ripening. Senescence associated genes and gene products.

Unit III: Functional and ultra structural changes in chloroplast membranes, mitochondria and cell wall during senescence and ripening.

Unit IV: Ethylene biosynthesis, perception and molecular mechanism of action; regulatory role of ethylene in senescence and ripening, biotechnological approaches to manipulate ethylene biosynthesis and action.

Unit V: Alternate post harvest methodology and quality attributes. Scope for genetic modification of post harvest life on flowers and fruits.Uses of GM crops and ecological risk assessment.

VII. **Practical**

- Physiological and biochemical changes during senescence and ripening;
- Estimation of ethylene during senescence and ripening;

- Determination of Reactive Oxygen Species and scavenging enzymes;
- Measurement of dark and alternate respiration rates during senescence and ripening;
- Estimation of ripening related enzyme activity, cellulases, pectin methyl esterases, polygalacturonase, etc.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Readomg/ writing)
- Student presentation

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Physiological, biochemical and structural changes during scenecesnce and ripening.

X. Suggested Reading

Bartz JA and Brecht JK. 2003. *Post harvest physiology and pathology of vegetables*. Marcel Dekker Inc.

Davis PJ. 2004. *Plant Hormone: Biosynthesis, Signal transduction and action*. Kluwer Academic Publishers.

Dris R and Jain SM. 2004. *Production practices and quality assessment of food crops*, Vol. 4: Post harvest treatment and Technology. Kluwer Academic Publisher.

Khan NA. 2006. *Ethylene action in plants*. Springer Verlag.

Knee M. 2002. *Fruit Quality and its Biological Basis*. Sheffield Academic Press, CRC Press.

Nooden LD. 2004. *Plant cell death processes*. Elsevier Science, USA.

Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Post harvest biology and technology of fruits, vegetables and flowers*. Blackwel Publishing, Iowa, USA.

Seymour G, Taylor J and Tucker G. 1993. *Biochemistry of fruit ripening*. Edited Chapman andHall, London.

Valpuesta V. 2002. *Fruit and vegetable biotechnology*.Woodhead Publishing Limited, Cambridge, England.

I. Course Title : Recent Trends in Food Preservation

II. Course Code : PHM-602

III. Credit Hours : (1+1)

IV. Why this course ?

Commendable production with short storage life and strategic selling limits the produce to huge loss after harvest. To prevent the postharvest loss preservation of produce with appropriate technique enhances the finished product shelf life nearly 10 to 30 times. Food processing combines raw food ingredients to produce marketable food products that can be easily prepared and served by the consumer. Emerging technologies which have already found in the food industry or related sector are High pressure processing, pulsed electric fields, ultrasound, and cold plasma. The basic principles of these technologies as well as the state of the art concerning their impact on biological cells, enzymes, and food constituents.

V. Aim of the course

The present subject imparts knowledge on recent advancement in food preservation technologies. The basic principles of preservation technologies as well as the state of the art concerning their impact on biological cells, enzymes and food constituents.

Current and potential applications will be discussed, focusing on process-structure-function relationships, as well as recent advances in the food process development that make foods.

The course is organized as follows:

No	Blocks	Units
1	Hurdle technology and recent advances	I Hurdle technology II Thermal and Non-thermal technology III Recent food preservation techniques
2	Enzyme applications and quality parameters	I Enzyme and their applications II Quality specifications and standards

VI. Theory

Block 1: Hurdle technology and recent advances

Unit I: Hurdle technology, Principles of Hurdle Technology, Minimally Processed foods, Intermediate moisture foods, role of water activity in food preservation, Chemicals and biochemicals used in Food Preservation- Natural food preservatives, bacteriocins.

Unit II: Thermal and Non-thermal technology, Advanced Thermal and Nonthermal Technology- Pulsed electric field, microbial inactivation, application, present status and future scope. Fundamentals and Applications of High Pressure Processing to Foods, Advances in Use of High Pressure to Processing and Preservation of Plant Foods, Commercial High-Pressure Equipment. Food Irradiation – an Emerging Technology.

Unit III: Recent food preservation techniques, Ultraviolet Light and Food Preservation; Microbial Inactivation by Ultrasound; Use of oscillating Magnetic Fields. Nonthermal Technologies in Combination with Other Preservation Factors. Preservation by ohmic heating-Advances in Ohmic Heating and Moderate Electric Field (MEF) Processing; Radio-Frequency Heating in Food Processing;Current State of Microwave Applications to Food Processing.Supercritical Fluid Extraction: An Alternative to Isolating bioactive compounds.

Block 2: Enzyme applications and quality parameters

Unit I: Enzyme and their applications. Enzyme and their application in food processing, Principles of food biotechnology, fermentation and enzyme mediated food processing, production of high value products such as Single Cell Protein, nutritional additives, pigments and flavours.

Unit II: Quality specifications and standards. Quality parameters and specifications, Food laws and standards, HACCP, FSSAI amendments, ISO, FDA.

VII. Practical

- Determination of thermal resistance of food spoilage microorganisms;
- Determination of thermal death curve;
- Thermal process calculations;
- Demonstration of hurdle approaches in fruits and vegetables preservation.

Enumerate the hurdle approaches in food processing;
- Detection of microbes in each hurdle. Study of shelf life of fresh cut produce in each hurdle;
- Study of fresh cut produce packing, storage temperature and microbial interaction;
- Study of thermal and non thermal application in food preservation;
- Study of moisture content in food their water activity;
- Demonstration of microwave technology in fresh produce preservation and drying;
- Determination of dry matter content in food using microwave technology;
- Study the use of enzymes in different fruit juice extraction, quantification, time – Pectinase/cellulose and others;
- Incubation techniques of enzymes using fermenter for juice extractions;
- Group discussions on current market potential of hurdle technology – Prose and cons;
- Visit to advanced food processing unit;
- Visit to SCFE unit.

VIII. Teaching Methods/ Activities
- Lectures
- Assignment (Reading/ Writing)
- Student presentation

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the latest methods and techniques in preservation of food particularly of horticultural produce

X. Suggested Reading

Barbosa CGV, Pothakamury UR, Palou E and Swanson BG. 1998. *Nonthermal Preservation of Foods*, Marcel Dekker Inc., ISBN 9780824799793.

Karel M and Lund DB. 2003. *Physical Principles of Food Preservation* (2nd Edition), CRC Press, ISBN 9780824740634.

Sun Da-Wen (Ed.) 2014. *Emerging Technologies for Food Processing* (2nd Edition), Elsevier, ISBN 9780124114791.

Tewari G and Juneja V. 2007. *Advances in thermal and nonthermal food.* Blackwell Publishing, ISBN 9780813829685.

Websites

http://www.sciencepublishinggroup.com/specialissue/specialissueinfo?jo

http://www.ijpab.com/form/2017%20Volume%205,%20issue%206/IJPAB-2017-5-6-363-371.pdf

https://www.omicsonline.org/conferences-list/food-processing-technologies-and-advances-in-food-preservation

https://www.elsevier.com/books/advances-in-cold-plasma-applications-for-food-safety-and-preservation/bermudez-aguirre/978-0-12-814921-8

I. Course Title : Management and Utilization of Horticultural Processing Waste

II. Course Code : PHM-603

III. Credit Hours : (3+0)

IV. Why this course ?

Processing of fruit and vegetables generates varying level and kinds of wastage that can be managed differently. With the rapid progress in establishment of processing industries in our country on account of liberal government policies, the importance of waste management has become an essential and integral part of plant design as the inappropriate disposal of wastage has already caused great loss to environment and public health. Food processing is a capital intensive, high energy and water consuming, and moderate to highly polluting industry. However, one can minimize adverse effects on environment and public health and may also augment profit of processing unit by judicious disposal and utilization of waste materials. They can be used in composting, cattle feeding and biogas generation and certain types may also be utilized in production of value added products.

V. Aim of the course

Understanding the utilization and efficient management of waste from horticultural processing industry.

The course is organized as follows:

No	Blocks	Units
1	Waste treatment and disposal methods	I Introduction II Waste treatment processes III Waste disposal methods
2	Valorisation of wastes	I Recovery of useful products II Treatment of solid and liquid waste

VI. Theory

Block 1: Waste treatment and disposal methods

Unit I: Introduction: Waste and its consequences in pollution and global warming. Need for waste management. Waste and its classifications and characterization-sampling methods, analysis and standards for waste discharge. Importance of point and nonpoint sources of wastes, Solid and liquid wastes.

Unit II: Waste treatment processes: BOD, COD, DO, TS VS, ash, and different unit operations in waste treatment processes.

Unit III: Waste disposal methods: Nature of waste from processing industry and their present disposal methods. Waste segregation, Primary secondary and tertiary waste treatment processes, Conventional and non-conventional waste treatment processes, aerobic and anaerobic waste treatment processes.

Block 2: Valorisation of wastes

Unit I: Recovery of useful products: Valorization of wastes: Recovery of useful products and by-products from waste, viz., organic acids, bioethanol, biobutanol, colour, essence, pectin, oils, etc. animal feed and single cell protein.

Unit II: Treatment of solid and liquid waste: Technology of treatment of solid and liquid wastes from fruit and vegetable industries. Immobilized bioreactor in waste treatment.Anaerobic bioreactor and energy production.Circular economics and waste management.

VII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Student presentations

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Can identify the problems related waste treatments and disposal methods
- Problem related valuation of waste and recycling of waste

IX. Suggested Reading

Arvanitoyannis IS. 2008. *Waste Management for the Food Industries*, Academic Press, ISBN 9780123736543.

Joshi VK and Sharma SK. 2011. *Food Processing Waste Management: Treatment and Utilization Technology*, New India Publishing Agency, ISBN 9789380235592.

Waldron K. Ed. 2007. *Handbook of waste management and co-product recovery in food processing*, CRC Press, ISBN 9780849391323.

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https://www.cabdirect.org/cabdirect/abstract/20153005486
http://www.3rmanagement.in/service/horticulture-waste-management/

I. Course Title : Supply Chain Management of Perishables

II. Course Code : PHM 604

III. Credit Hours : (2+0)

IV. Why this course ?

Supply chain management is the management of the flow of goods and services and includes all processes that transform raw materials into final products. It involves the active streamlining of a business's supply-side activities to maximize customer value and gain a competitive advantage in the marketplace. SCM represents an effort by suppliers to develop and implement supply chains that are as efficient and economical as possible. Supply chains cover everything from production to product development to the information systems needed to direct these undertakings. Because of this, effective supply chain management also requires change management, collaboration and risk management to create alignment and communication between all the entities.

V. Aim of the course

To understand the intricacies of perishable supply chain and its management.

The course is organized as follows:

No	Blocks	Units
1	Supply chain management of perishables	I Introduction II Intrinsic Issues III Support system in supply chain- – Infrastructure IV. Support system in supply chain- Finance V. Support system in supply chain- Government

VI. Theory

Block 1: Supply chain management of perishables

Unit I: Introduction. Role of supply chain and logistics, Challenges faced in supply chain, Input suppliers, Farm output: Market intermediaries, Processors, Retailers.

Unit II: Intrinsic Issues: Perishability, Quality, Grading, Risk: Sources of risk, Classification of Agricultural risk- Production risk, Market and Price risk. Mnagement of risk.

Unit III: Support system in supply chain- Infrastructure: definition, role. Transport network, Cold storage, organised market, etc. Information technology-Enterprise resource planning, E-Choupal, Mobile Technology, web portal on agri-market information.

Unit IV: Support system in supply chain- Financial Systems: Introduction, Role and Relevance, Problems in Synchronization, Role of Technology; Credit Structure in India -Reserve Bank of India (RBI), NABARD; Commodity Markets, Corporates in Agribusiness.

Unit V: Support system in supply chain- Role of Government: Introduction; Agencies- As a Direct Player. Measures for improving supply chain and its effectiveness, involvement of organized retailers.

VII. Practical

- Present scenario of supply chain management;
- Case Study: Supply chain management of fruits and vegetables in Safal daily fresh/ APMC/ Reliance Fresh/ Amul/ D-Mart/ Spencer Retail/ Vipani/ Farmers Bazars/ Farm Fresh/ Apni Mandi, etc. based on regional importance.

VIII. Teaching Methods/ Activities

- Lectures
- Assignment (Reading/ Writing)
- Student presentationz

IX Learning outcome

After successful completion of this course, the students are expected to be able to:

- Can identify the problems related waste treatments and disposal methods

X. Suggested Reading

Chandrasekaran N and Raghuram G. 2014. *Agribusiness Supply Chain Management,* CRC Press, ISBN 9781466516755.

Chopra S and Meindl P. 2007. *Supply chain management: strategy, planning, and operation* (3rd Edition), Pearson Education, Inc.,ISBN 0132086085.

Websites

http://www.scmr.com/
https://blog.kinaxis.com/
http://www.supplychainnetwork.com/
http://supplychaininsights.com/
http://www.supplychain247.com/

I. Course Title : Export Oriented Horticulture

II. Course Code : PHM-605

III. Credit Hours : (1+0)

IV. Why this course ?

This course relates the national economy which is dependent on the contribution of the export-oriented income. Export oriented policies and laws must be followed by the growers to meet the requirement of the importing countries.

V. Aim of the course

To acquaint the students with the export oriented requirements of horticultural crops.

The course is organized as follows:

No	Blocks	Units
1	Product specifications and sanitary measures	I Introduction II Produce specifications and standards III Export oriented sanitary measures
2	Export related policies	I Export implications II Treatment of solid and liquid waste

VI. Theory

Block 1: Product specifications and sanitary measures

Unit I: Introduction: India's position and potentiality in world trade; export promotion zones in India. Export and import policy, problem in export of fresh horticultural produce, export infrastructure (sea port, airport, bulk storage facilities, irradiation, Vapour Heat Treatment, quarantine, transportation, etc.,).quarantine need, major export destination and competing nations for selected crops.

Unit II: Produce specifications and standards: Scope, produce specifications, quality and safety standards for export of fruits, viz., mango, grape, litchi, pomegranate, walnut, cashewnut, etc., vegetables, viz., onion, chilli, okra, bitter gourd, gherkin, etc., flowers, viz., rose, carnation, chrysanthemum, gerbera, specialty flowers, etc., cut green and foliage plants.

Unit III: Export oriented sanitary measures: Processed and value-added products, Postharvest management for export including packaging and cool chain; HACCP, Codex alimentarius, ISO certification; APEDA and its role in export, WTO and its implications, sanitary and phyto-sanitary measures. Codex norms and GAP and SOP for export of smajor horticultural crops from India.

Block 2: Export related policies

Unit I: Export implications: Export of seed and planting material; implications of PBR, treatments of horticultural produce, MRL for export of horticultural produce.

Unit II: Export oriented regulatory issues: Agriculture Export Policy, Export procedure; EXIM Policy, APMC act, Auction Centres, Regulatory issues of Ministry of Commerce, GoI.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Student presentation

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- entry barriers, covering issues such as economies of scale, high capital investments, difficult access to distribution channels and markets, etc.
- bargaining power of buyers, which relates to issues such as the level of concentration of buying power, buyers' access to information, switching opportunities and costs, etc.

IX. Suggested Reading

Bartz JA. and Brecht JK. 2002. *Postharvest Physiology and Pathology of Vegetables* (IInd Edition) Marcel Dekkar, Inc, New York.

Bhattacharjee, SK. 2006. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ.

Bose TK and Yadav LP. 1989. *Commercial Flowers*. NayaProkash, Kolkata. Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. NayaProkash.

Chadha KL. 1995. *Advances in Horticulture*. Vol. XII. Malhotra Publ. House.

Islam CN. 1990. *Horticultural Export of Developing Countries: Past preferences, future prospects and policies*. International Institute of Food Policy Research, USA.

Reddy S, Janakiram T. Balaji T, Kulkarni S and Misra RL. 2007. *Hightech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi.

Sheela VL. 2007. *Flowers in Trade*. New India Publ. Agency.

I. Course Title : Food Additives

II. Course Code : PHM 606

III. Credit Hours : (1+1)

IV. Why this course ?

Food additives have been used for centuries to improve and preserve the taste, texture, nutrition and appearance of food. Food additives and preservatives are used in today's food supply to prevent foodborne illness, enable the transportation of food to areas that otherwise wouldn't be possible, and for the efficient manufacture of products to consistently meet the established quality standards. Although there may be certain ill effects of additives and preservatives in food, they increase its shelf life and help retain the flavour, color, and texture. They also help maintain or increase the nutritive value of food. Hence this customized course.

V. Aim of the course

To understand the chemistry of food additives and their functions in food processing This course is organized as follows:

No	Blocks	Units
1	Quality control of horticultural products	I Importance of food additives II Methods of preservation III Different additives types IV Flavour technology V Use of functional ingredients and safety and toxicological evaluation

VI. Theory

Block 1: Food Additives

Unit I: Importance of food additives in processing and preservation of horticultural produce by food additives. Food additives-definitions, classification, international numbering systems and functions.

Unit II: Principles and methods of preservation by use of sugar, salt, spices, essential oils, vinegar, mode of action of chemical preservatives.

Unit III: Antioxidants, colours and flavours (synthetic and natural), emulsifiers, sequester ants, humectants, hydrocolloids, sweeteners, acidulants, buffering salts, anticaking agents, clarifying agents, etc. – uses in horticulture foods and functions in formulations.

Unit IV: Flavour technology: types of flavours, flavour generated during processing – reaction flavours, flavour composites, stability of flavours during food processing, flavour emulsion, essential oils and oleoresins, etc.

Unit V: Uses of enzymes in extraction of juices. Pectic substances and their role as jellifying agents.Protein, starches and lipids as functional ingredients, functional properties and applications in horticultural food. Safety and toxicological evaluation of food additives: GRAS-tolerance levels and toxic levels in foods, LD_{50} value.

VII. Practical

- Extraction of fruit and vegetable juices using enzymes clarification;
- Role of additives and preservatives in RTS, cordial, squash, concentrate, syrup, jam, jelly, marmalade, ketchup, sauce, preserves, chutneys, pickles, candies, crystallized products;
- Estimation of benzoic acid, sulphur-di-oxide;
- Estimation of pectins.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Exposure visits
- Student presentation

IX. Learning outcome

After successful completion of this course, the students are expected to be able to understand:

- Importance of food additives in processing and preservation of horticultural produce
- About Flavour technology
- Safety and toxicological evaluation of food additives

X. Suggested Reading

Branen AL, Davidson PM, Salminen S and Thorngate III JH. 2001. *Food Additives* (2nd Edition), Marcel Dekker Inc., ISBN 0824793439.

DGHS Manual 8: *Manual of Methods of Analysis of Foods-Food Additives*.

Gerorge AB. 1996. *Encyclopedia of Food and Color Additives*. Vol. III. CRCPress.

Madhavi DL, Deshpande SS and Salunkhe DK. 1996. *Food Antioxidants: Technological, Toxicological and Health Perspective*. Marcel Dekker.

Michael and Ash I. 2008. *Handbook of Food Additives* (3rd Edition), Synapse Information Resources, Inc., ISBN 9781934764008.
Nagodawithana T and Reed G. 1993. *Enzymes in food processing*. Academic Press.
Ötleº S. Ed. 2005. *Methods of Analysis of Food Components and Additives*, CRC Press, ISBN 9780849316470.
Taylor AJ. and Linforth RST. 2010. *Food Flavour Technology* (2nd Edition), Wiley- Blackwell, ISBN 9781405185431.
Wood R, Foster L, Damant A and Key P. 2004. *Analytical Methods for Good Sdditives*, CRC Press, ISBN 084932534X.

Websites

Additives and colors FDA-https://www.fda.gov/food/ingredientspackaginglabeling/foodadditivesingredients/ucm094211.htm
https://www.faia.org.uk/
https://www.eufic.org/en/whats-in-food/category/additives

I. Course Title : Advances in Processing of Plantation, Spices, Medicinal and Aromatic Plants
II. Course Code : PHM-607
III. Credit Hours : (3+0)

IV. Why this course ?

This course deals with post-harvest operations, processing and value addition details of plantation, spices, medicinal and aromatic plants. This course would be very useful for everyone who so ever is interested to know about harvesting and handling of spices, plantation, medicinal and aromatic plants.

V. Aim of the course

To familiarize with advances in processing of plantation, spices, medicinal and aromatic plants

The course is organized as follows:

No	Blocks	Units
1	Handling and utilization of plantation, spice, medicinal and aromatic plants	I Introduction II By product utilization III Value addition of medicinal and aromatic plants
2	Essential oil utilization and their storage	4.Recovery of useful products 5.Treatment of solid and liquid waste

VI. Theory

Block 1: Handling and utilization of plantation, spice, medicinal and aromatic plants

Unit I: Introduction: Commercial uses of spices and plantation crops. Introduction to processing and products in plantation and spice crops. Significance of on farm processing and quality of finished products. Processing of major spices, extraction of oleoresin and essential oils. Processing of produce from plantation and spice crops.

Unit II: By product utilization:By product utilization in plantation crops for coir production, mushroom culture, cocopeat, bee keeping, toddy tapping, Oil cake production and utilization, vermi-composting, Fuel wood and timber wood from perennial spices and plantation crops (crops, viz., coconut, areca nut, cashew nut, oil palm, palmyrah, date palm, cocoa, tea, coffee, rubber, etc. cardamom, black pepper, ginger, turmeric, chilli and paprika, vanilla, cinnamon, clove, nutmeg, allspice, coriander, fenugreek, curry leaf, etc.).

Unit III: Value addition of medicinal and aromatic plants: Value addition on aromatic oils and medicinal herbs. Principles and practices of different types of extraction – distillation, solvent extraction, enfleurage, soxhlet, supercritical fluid extraction, phytonics, counter current extraction. Commercial uses of essential oils, aroma therapy.Commercial utilization of spent material.

Block 2: Essential oil utilization and their storage

Unit I: Quality determination of essential oils: Qualitative determination of essential oils. Quality analysis and characterization through chromatographs.

Unit V: Storage of essential oils: Storage of essential oils. Utilization of spent material of medicinal and aromatic crops in manufacture of agarabatti, organic manures and other useful products. Detoxification of waste materials. Role of spent material in bio-control of diseases and pest in organic farming. Role of micro-organisms in conversion of waste in to useful products.

VII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Student presentation

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Learn utilization and processing of spice, plantation, medicinal and aromatic plants
- Apply appropriate processing technique to the crop related processing technique

IX. Suggested Reading

Afoakwa EO. 2016. *Cocoa Production and Processing Technology*, CRC Press, ISBN 9781138033825.

Chakraverty A, Majumdar AS, Raghavan GSV and Ramaswamy HS. 2003. *Handbook of Postharvest Technology: Cereals, Fruits, Vegetables, Tea, and Spices*, CRC Press, ISBN 9780824705145.

Chi-Tang Ho, Jen-Kun Lin and Fereidoon Shahidi. 2008. *Tea and Tea Products: Chemistry and Health-Promoting Properties*, CRC Press, ISBN 9780849380822.

Kumar N, Khader JBMM, Rangaswami P., and Irulappan I. 2017. *Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants* (2nd Edition), Oxford & IBH Publishers, ISBN 9788120417762.

Pruthi JS. 1993. *Major Spices of India Crop Management Postharvest Technology*, ICAR Publication, ISBN 1234567147556.

Siddiqui MW. 2015. *Postharvest Biology and Technology of Horticultural Crops: Principles and Practices for Quality Maintenance*, CRC Press, ISBN 9781771880862.

Websites

https://www.cabdirect.org/cabdirect/abstract/20006781145:
https://www.springerprofessional.de/en/value-addition-in-flowers/4657550

I. Course Title : Value Addition in Ornamental Crops

II. Course Code : PHM 608

III. Credit Hours : (1+1)

IV. Why this course ?

Ornamental crops provide better income from a unit area with higher profitability. The production of flower crops has increased significantly and there is huge demand for floricultural products in the world resulting in growing international flower trade. Value addition in floriculture increases the economic value and consumer appeal of any floral commodity. This course will be useful as a source of income generation.

V. Aim of the course

To acquaint the students about the scope and ways of value addition in ornamental crops.

The course is organized as follows:

No	Blocks	Units
1	Value addition of flowers	I Introduction II Value addition of flower crops III Neutraceuticals from petals
2	Floral arrangements and women empowerment	I Floral arrangements II Women empowerment

VI. Theory

Block 1: Value addition of flowers

Unit I: Introduction: Importance, opportunities and prospects of value addition in floriculture; national and global scenario; production and exports, supply chain management.

Unit II: Value addition of flower crops: Dry flower making including pot pourries, their uses and trade; extraction technology, uses, sources and trade in essential oils; aroma therapy; pigment and natural dyes extraction technology, sources, uses and trade.

Unit III: Neutraceuticals from petals: Pharmaceutical and neutraceutical compounds from flower crops; petal embedded hand made paper making and uses, preparation of products like gulkand, rose water, gulroghan, attar, pankhuri.

Block 2: Floral arrangements and women empowerment

Unit I: Floral arrangements: Floral craft including bouquets, garlands, flower arrangements, etc. tinting (artificial colouring) of flower crops;

Unit II: Women empowerment: Women empowerment through value added products making.

VII. Practical

- Dry flower making including pot pourries; extraction technology, uses, sources and trade in essential oils;
- Pigment and natural dyes extraction technology;
- Pharmaceutical and neutraceutical compounds from flower crops;
- Preparation of products like *gulkand*, rose water*gulroghanattar, pankhuri*;
- Petal embedded handmade paper making;
- Floral craft including bouquets, garlands, flower arrangements, etc.;
- Tinting (artificial colouring) of flower crops.

VIII. Teaching Methods/ Activities

- Lecture
- Assignment (Reading/ Writing)
- Student presentation
- Group Work/ Seminars
- Product preparation and income generation assessment

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Will be helpful in converting waste into wonder by making potpourris, greeting cards, etc.
- Students can give training to women and create a source of employment to rural women

X. Suggested Reading

Bhattacharjee SK and De LC. 2004. *Advances in Ornamental Horticulture* Vol. V, Pointer publishers, Jaipur.

Gary L. McDaniel. 1989. *Floral design and arrangement*. A Reston Book. Prentice hall. New Jersey.

Lauria A and Victor HR. 2001. *Floriculture – Fundamentals and Practices*. Agrobios. Lesniewicz Paul. 1994. *Bonsai in your home*. Sterling publishing Co, New York.

Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios.

Randhawa GS and Mukhopadhyay A. 2000. *Floriculture in India*, Allied publishers, India.

Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hightech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi.

Salunkhe K, Bhatt NR and Desai BB. 2004. *Postharvest biotechnology of flowers and ornamental plants*. NayaProkash, Kolkata.

Websites

http://www.vedamsbooks.com/no103218/user_forgot_pass.php
https://www.springerprofessional.de/en/value-addition-in-flowers/4657550
www.ihc2018.org/en/S29.html

Journals on Postharvest Management of Horticultural Crops

Sr. No.	Name of the Journal	ISSN No.
1.	*Annual Review of Food Science and Technology*	ISSN 19411421, 19411413
2.	*Comprehensive Reviews in Food Science and Food Safety*	ISSN 15414337
3.	*Trends in Food Science and Technology*	ISSN 09242244
4.	*Food Chemistry*	ISSN 03088146
5.	*Food Microbiology*	ISSN 10959998, 07400020

Sr. No.	Name of the Journal	ISSN No.
6.	*Postharvest Biology and Technology*	ISSN 09255214
7.	*Food Research International*	ISSN 09639969
8.	*Critical Reviews in Food Science and Nutrition*	ISSN 15497852, 10408398
9.	*Journal of Food Engineering*	ISSN 02608774
10.	*International Journal of Food Microbiology*	ISSN 01681605
11.	*Food Control*	ISSN 09567135
12.	*Innovative Food Science and Emerging Technologies*	ISSN 14668564
13.	*Food and Bioprocess Technology*	ISSN 19355130, 19355149
14.	*LWT-Food Science and Technology*	ISSN 10961127, 00236438
15.	*Journal of Functional Foods*	ISSN 17564646
16.	*Food Quality and Preference*	ISSN 09503293
17.	*Journal of Food Composition and Analysis*	ISSN 08891575, 10960481
18.	*Plant Foods for Human Nutrition*	ISSN 09219668, 15739104
19.	*Current Opinion in Food Science*	ISSN 22147993
20.	*Food Packaging and Shelf Life*	ISSN 22142894
21.	*Journal of the Science of Food and Agriculture*	ISSN 10970010, 00225142
22.	*International Journal of Food Science and Technology*	ISSN 13652621, 09505423
23.	*Journal of Food Science*	ISSN 00221147
24.	*Journal of Food Protection*	ISSN 0362028X
25.	*Phytochemical Analysis*	ISSN 09580344, 10991565
26.	*Food Reviews International*	ISSN 15256103, 87559129
27.	*European Food Research and Technology*	ISSN 14382377, 14382385
28.	*Biosystems Engineering*	ISSN 15375110, 15375129
29.	*Agribusiness*	ISSN 15206297, 07424477
30.	*Journal of Sensory Studies*	ISSN 08878250
31.	*Journal of Texture Studies*	ISSN 00224901
32.	*International Journal of Food Properties*	ISSN 10942912, 15322386
33.	*International Journal of Food Sciences and Nutrition*	ISSN 09637486, 14653478
34.	*Journal of Food Science and Technology*	ISSN 00221155
35.	*Advances in Food and Nutrition Research*	ISSN 10434526
36.	*Journal of Food Process Engineering*	ISSN 17454530, 01458876
37.	*British Food Journal*	ISSN 0007070X
38.	*Journal of Food Quality*	ISSN 01469428, 17454557
39.	*Food Science and Technology International*	ISSN 10820132
40.	*Irish Journal of Agricultural and Food Research*	ISSN 07916833, 20099029
41.	*Journal of Food Processing and Preservation*	ISSN 01458892
42.	*Stewart Postharvest Review*	ISSN 17459656
43.	*International Journal of Food Science*	ISSN 23145765, 23567015
44.	*Food Science and Technology*	ISSN 01012061, 1678457X
45.	*International Food Research Journal*	ISSN 19854668
46.	*International Food and Agribusiness Management Review*	ISSN 15592448, 10967508
47.	*Food Science and Technology Research*	ISSN 13446606
48.	*International Journal of Food Engineering*	ISSN 15563758, 21945764
49.	*Journal of Horticultural Research*	ISSN 23005009, 23533978
50.	*International Journal of Postharvest Technology and Innovation*	ISSN 17447550, 17447569
51.	*Food Technology*	ISSN 00156639
52.	*Open Nutraceuticals Journal*	ISSN 18763960
53.	*Advance Journal of Food Science and Technology*	ISSN 20424868, 20424876

ANNEXURE I

List of BSMA Committee Members for Horticultural Sciences

(Fruit Sciences/ Vegetable Sciences/ Floriculture and Landscape Architecture/ Plantation, Spices, Medicinal & Aromatic Plants/ Post-harvest Technology)

S.No.	Name and Address	Specialization
1.	**Dr RK Pathak** **Former Director** Central Institute for Subtropical Horticulture, Lucknow C-906, Oberoi Excutive, Goregaon, East Mumbai-400 063 Email: pathakramkripal@gmail.com Mob.: 09454974422/ 08828486737	**Chairman**
2.	**Dr K M Indiresh** **Registrar** University of Horticultural Sciences, Bagalkot, Karnataka Email; registrar@unsbagakot.edu.in; indiresh.kabbali@gmail.com Mob.: 09480696389	**Convener**
3.	**Dr Krishnan Kumar** **Professor & Head** Department of Fruit Science, College of Horticulture Dr YS Parmar University of Horticulture and Forestry Nauni, Solan-173 230 Email: drkrishankumar@gmail.com Mob.: 09418020518	**Fruit Science**
4.	**Dr M K Rana** **Professor** Department of Vegetable Science Chaudhary Charan Singh Haryana Agricultural University Hisar, Haryana-125 004 Email: maheshk2@hau.ernet.in Mob.: 0941634573	**Vegetable Science**
5.	**Dr K V Prasad** **Director** ICAR-Directorate of Floricultural Research College of Agriculture, Shivajinagar, Pune-411 005 Email: directordfr@gmail.com Mob.: 09868149259	**Floriculture**

S.No.	Name and Address	Specialization
6.	**Dr Amit Baran Sharangi** **Professor & Head** Department of Spices & Plantation Crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur Email: drabsharangi@yahoo.co.in Mob.: 09433313117	**Spices & Plantation crops**
7.	**Dr Miniraj** **Professor** Department of Plantation Crop and Sciences, Kerala Agricultural University, Thrissur-680 656 Email: n.miniraj@kau.in Mob.: 09388673785	**Spices & Medicinal**
8.	**Dr Laxminarayan Hegde** **Department of Medical Crops, Arabhavi,** University of Horticultural Sciences, Bagalkot Email: hegdelax@gmail.com hrspepper@gmail.com Mob.: 08762189133	**Horticulture**
9.	**Dr M. Lakshminarayana Reddy** **Dean (Hort.)** Dr YSR Horticulture University, Venkatarmanagudem West Godavari Dist, Andhra Pradesh-534 101 Email: dh@drysrhu.edu.in Mob.: 09490402052	**Horticulture**

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Contents

Acknowledgements

We place on record our profound gratitude to Dr Trilochan Mohapatra, the Hon'ble Director General, ICAR, New Delhi for providing the opportunity to revise the Syllabi for PG and Ph.D education in Forestry. Our heartfelt thanks are due to Dr N.S. Rathore, DDG (Education), ICAR and Prof. Arvind Kumar, Hon'bleVice Chancellor, RLBCAU, Jhansi and Chairman, National Core Committee Dr G. Venkateshwarlu, ADG (EQ&R) for providing support and guidance in this important academic venture.

Dr H C Sharma, Hon'ble Vice Chancellor, YSP UHF, Nauni, Solan and Dr P K Mahajan, Dean, College of Forestry and Convener, BSMA took special interest in this committee and holding 1st meeting in their esteemed institute and providing administrative support during the said meeting. The BSMA committee is thankful to Hon'ble Vice Chancellor, CCS HAU, Hissar and Dr R.S. Dhillon, Head, Department of Forestry, College of Agriculture, Hissar and Coordinator for providing support for holding 2nd meeting at their institute. Our sincere gratitude to Hon'ble Vice Chancellor, Dr Bala Shabeb Sanwant Konkan Krishi Vidyapeeth, Dapoli (Maharashtra) and Dr S.S. Narkhede, Dean, College of Forestry for organizing two days workshop by him at Dapoli, where more than 36 Forestry scientists deliberated on the syllabi.

Our thanks are also due to different leading institutes of the country in Forestry education such as FRI, Dehradun, BAU, Ranchi, KAU, Thrissur, UAS, Dharwad, NAU, Navsari, SKUAST, Jammu and Kashmir for allowing their scientists to participate in the workshop and meetings and the valuable suggestions for the formulation of this syllabi.

Pawan Kumar Mahajan
Convener, BSMA (Forestry)
L K Dashora
Chairman, BSMA (Forestry)

Preamble

The world of Forestry is changing rapidly. The multi-valuable nature of forests is gaining wider recognition, thus, leading to increased understanding of the linkage between forests and society. Forests are significant to the well being of society providing multiple services and products *i.e.* tangible and intangible. Moreover, in the present era of climate change, our forests are crucial not only for supplying various products and services but also for ensuring a healthy environment. From providing livelihood security to generating business ventures; from being sources of rich biodiversity to carbon resources, the usefulness of forests to humankind indeed is wide-ranging. Forest as a commodity is to be managed scientifically to enhance its production and productivity and protection of environment as well as sustenance of our agriculture. Higher Forestry education has an important role to play in the future of the world's forests. The future decision makers; the students of today; will need to possess adequate skills to be able to meet the future challenges.

To produce high degree competence and skill oriented world class forestry professionals, Forestry education needs to be reoriented so as to meet the challenges of high forest productivity and global market along with eco-friendly environment.

The State Agricultural Universities undertake Forestry education with unique facilities and linkage between agriculture, horticulture, animal husbandry and forestry. To make the undergraduate degree programme more relevant and skill oriented quality education, the 5th Deans Committee of ICAR, New Delhi revised the B.Sc. Forestry programme with introduction of students' READY programme to develop entrepreneur skills among the Forestry students.

In India, Forestry education was introduced at the University level by starting M.Sc. Forestry in 1976 at Dr YS Parmar University of Horticulture and Forestry, Nauni (HP). Thereafter, many Agriculture Universities started UG, PG and Ph.D. programme in Forestry with the directive of MoEF and ICAR. Today, about 50 institutes of State/ Central/ Private University in 21 states of the country are offering different degree programmes in Forestry. The existing single M.Sc. Forestry programme is quite inadequate to meet the present and envisaged human resource requirement. Further, at present, PG degree in Forestry is being awarded under different nomenclatures by various Universities as per their own convenience, and no common courses are given to students for the same degree at M.Sc. or Ph.D level. In order to bring uniformity in the system of imparting Forestry education at University level, ICAR, New Delhi (5th Dean's Committee) recommended that each University which offers B.Sc programme in Forestry should have four departments namely: Silviculture and Agroforestry, Forest Biology and Tree Improvement, Forest Products and Utilization and Forest Resource Management.

The BSMA Committee on Forestry has been constituted by National Core Group (ICAR) to re-structure the M.Sc. and Ph.D programme in Forestry in accordance to the changes made in B.Sc. Forestry curriculum by 5th Dean's Committee, ICAR, New Delhi. In order to bring excellence in teaching and research at Master's and Ph.D. levels and making the degrees more professional and saleable, the core courses have been offered in those fields where opportunities are very high for employability and for development of entrepreneurship.

The BSMA Committee for Forestry organized two meetings at College of Forestry, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan and College of Agriculture, CCS Haryana Agricultural University, Hissar (Haryana), respectively, and a two-day workshop at College of Forestry, Dr Balasahib Swant Konkan Krishi Vidyaapeeth, Dapoli, Maharastra with participation from Agricultural Universities and other stakeholders from industries, State Forest Departments to develop the curricula. The envisaged M.Sc. and Ph.D. programmes have been restructured along with inclusion of new courses on important global issues like climate change, Biodiversity conservation, information technology, GIS, etc. in the syllabi. These M.Sc. and Ph.D. programmes are as follows:

1. Silviculture and Agroforestry (SAF)
2. Forest Biology and Tree Improvement (FBTI)
3. Forest Products and Utilization (FPU)
4. Forest Resource Management (FRM)

It is a belief of BSMA Committee on Forestry that the restructured PG academic programme including uniform degree nomenclature, course curricula and syllabi would prove ideal for generating world class professionals, human resource competent enough to meet the global challenges and competitiveness in Forestry and enhance their employability both in public and private sectors.

Career Opportunities

The new course programmes are more inclined to forestry and industry and have been deisgned in accordance to recent developments in the subject concerned hence will be helpful to fetch teaching, research and R&D jobs in colleges/ universities, research institutions and industries.

Pawan Kumar Mahajan
Convener, BSMA (Forestry)
L K Dashora
Chairman, BSMA (Forestry)

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Forestry
– Silviculture and Agroforestry

Course Title with Credit Load
M.Sc. (Forestry) in Silviculture and Agroforestry

Course Code		Course Title	Credit Hours
		Major Courses	
SAF 501*	I	Silviculture	2 + 1
SAF 502*	II	Forest Biometry	1 + 1
SAF 503*	I	Silvicultural Practices	1 + 1
SAF 504*	II	Agroforestry Systems	2 + 1
SAF 505*	I	Interactions in Agroforestry Systems	1 + 1
SAF 506	II	Modern Nursery Technologies	1 + 1
SAF 507	I	Plantation Forestry	2 + 1
SAF 508	II	Industrial Agroforestry	1 + 1
SAF 509	I	Climate Change and Conservation Silviculture	2 + 0
SAF 510	II	Trees and Shrubs for Agroforestry	1 + 1
SAF 511	I	Economics of Agroforestry Systems	2 + 1
SAF 512	II	Tree Seed Technology	2 + 1
SAF 513	I	Nutrient and Weed Management in Production Forestry	1 + 1
SAF 514	II	Crops and Live Stock Management in Agroforestry	2+0
		Minor Courses	
		Courses from Forest Biology and Tree Improveemnt or Forest Products and Utilization	08
		Supporting Courses	
FOR 511*	I	General Statistical Methods and Computer Applications	2+1
		Any other course relavent to MSc research problem	03
		Common Courses	
		Library and Information Services	1+0
		Technical Writing and Communications Skills	1+0
		Intellectual Property and its management in Agriculture	1+0
		Basic Concepts in Laboratory Techniques	1+0
		Agricultural Research, Research Ethics and Rural Development Programmes	1+0
SAF 591*	I/ II	Master's Seminar	1+0
		ii) Thesis Research	
SAF 599		Master's Research	0+30

*Compulsory Core Courses

Course Contents
M.Sc. (Forestry) in Silviculture and Agroforestry

I. Course Title : Silviculture

II. Course Code : SAF 501

III. Credit Hours : 2 + 1

IV. Aim of the course

To understand stand growth, development and provide knowledge regarding the application of silvicultural principles for the production and protection benefits from the forests.

V. Theory

Unit I

Forest ecosystems- Introduction to tropical/ temperate silviculture. Role of silviculture in forest and wild land management, major forest formations-classification, distribution, composition and structure. Vegetation dynamics- species richness-diversity indices. Vegetation forms of India and their productivity.
Forest ecosystem- structure and functioning, community development, competitive interactions in forest communities, forest succession, concepts and models of succession-Connell-Slatyer models, climax theories, tolerance.

Unit II

Ecophysiology of tree growth- effect of radiation and water relationship, mineral nutrients and temperature. Forest stand development – stand development, even-aged and uneven-aged stands, age and site quality. Tree architecture and its role in stand management.

Unit III

Stand density determination-stand density indices-stand density management-density management diagram, silvicultural treatments involved- thinning as a stand management tool, objectives of thinning, effects on growth and yield, thinning effect on economic yield of stands.
Forest site quality evaluation-direct and indirect methods.

Unit IV

Treatment analysis-silvicultural regimes- factors influencing choice of regimes, use of system analysis to determine regimes, models for evaluating silvicultural alternatives, development of silvicultural regimes to suit management objectives, optimum management strategies, silvicultural prescriptions for maximum production regime.

VI. Practical

- Visit to forest areas to study forest composition, classification, factors of locality, site quality, form and growth of forest trees- study plant succession- study stand density, changes on productivity- thinning effects;

VII. Suggested Reading

Daniel TW, Helms JA and Baker FS. 1979. *Principles of Silviculture.* McGraw-Hill Book Company.
Julius E. 1992. *Plantation Forestry in the Tropics*. Oxford University Press.
Khanna LS. 1996. *Principle and Practice of Silviculture*. International Book Distributors.
Khanna LS. 2015. *Theory and Practice of Indian Silviculture Systems*. Bio-Green Publisher.
Lamprecht. 1986. *Silviculture in the Tropics*.Verlag Paul Parey, Hamburg und Berlin.
Nyland RD, Laura S, Kenefic, Kimberly K, Bohn and Susan LS.2016 *Silviculture: Concepts and Applications* (III edition), Kindle Edition, USA.
Pascal. 1988. *Wet Evergreen Forests of the Western Ghats.*
Shepherd KR. 1986. *Plantation Silviculture.* Springer.
Smith DM, Larson BC, Ketty MJ and Ashton PMS. 1997. *The Practices of Silviculture- Applied Forest Ecology*. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Forest ecosystems- Introduction to tropical/ temperate silviculture	01
2.	Role of silviculture in forest and wild land management, major forest formations-classification, distribution, composition and structure	02
3.	Vegetation dynamics- species richness-diversity indices, various concepts	02
4.	Vegetation forms of India and their productivity	01
5.	Forest ecosystem- structure and functioning, community development, competitive interactions in forest communities	03
6.	Forest succession, concepts and models of succession-Connell-Slatyer models, climax theories, tolerance	03
7.	Ecophysiology of tree growth- effect of radiation and water relationship, mineral nutrients and temperature	02
8.	Forest stand development – stand development, even-aged and uneven-aged stands, age and site quality	02
9.	Tree architecture and its role in stand management	02
10.	Silvicultural treatments involved- thinning as a stand management tool, objectives of thinning, effects on growth and yield, thinning effect on economic yield of stands	03
11.	Forest site quality evaluation-direct and indirect methods	02
12.	Treatment analysis-silvicultural regimes- factors influencing choice of regimes, use of system analysis to determine regimes	03
13.	Models for evaluating silvicultural alternatives	02
14.	Development of silvicultural regimes to suit management objectives	02
15.	Optimum management strategies: silvicultural prescriptions for maximum production regime	02
	Total	32
	Practical	
1.	Visit to different forests to study forest composition and classification	4
2.	To study the effect of locality factor and determination of site quality in the different forests	4
3.	To study the plant sucession in different types of forests	2

Sr. No.	Topic	No. of Practical(s)
4.	To study the stand form, growth and stand density in major forest of the locality	2
5.	To carry out the productivity studies in different forests	2
6.	To study the impact of thinning in different periodic blocks/ selection forest	2
	Total	16

I. Course Title : Forest Biometry

II. Course Code : SAF 502

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding of students about tree and stand measurements, forest inventory and yield concepts.

V. Theory

Unit I

Measurement of tree parameters. Determination of tree age and dendrochronology for growth history and climate change studies.

Unit II

Estimation of volume, growth and yield of individual tree and forest stands. Preparation of volume tables. Application of yield and stand tables.

Unit III

Forest inventory, sampling methods adopted in forestry, Use of GIS in forest inventory. Quantification of regeneration and stand establishment. Measurement of crown density and crown ratios. Simulation techniques. Growth and yield prediction models – their preparation and applications.

VI. Practical

- Calculations of volume of felled as well as standing trees;
- Volume table preparation;
- Application of different sampling methods;
- Preparation of yield and stand table;
- Quantification of regeneration and stand establishment;
- Measurement of crown density and crown ratios;
- Crown profiling of trees and stand;
- Dendrochronological studies.

VII. Suggested Reading

Chaturvedi AN and Khanna LS. 1994. *Forest Mensuration*. International Book Distributor.
Ram Parkash 1983. *Forest Surveying*. International Book Distributor.
Sharpe GW, Hendee CW and Sharpe WE. 1986. *Introduction to Forestry*. McGraw-Hill.
Simmons CE. 1980. *A Manual of Forest Mensuration*. Bishen Singh Mahender Pal Singh, Dehradun.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Measurement of tree parameters	01
2.	Determination of tree age and dendrochronology for growth history and climate change studies	01
3.	Estimation of volume, growth and yield of individual tree and forest stands	02
4.	Preparation of volume tables	02
5.	Application of yield and stand tables	02
6.	Forest inventory, sampling methods adopted in forestry	02
7.	Use of GIS in forest inventory	01
8.	Quantification of regeneration and stand establishment	02
9.	Measurement of crown density and crown ratios	01
10.	Simulation techniques	01
11.	Growth and yield prediction models – their preparation and applications	01
	Total	16
	Practical	
1.	Calculations of volume of felled as well as standing trees. Preparation of yield and stand table. Crown profiling of trees and stand Dendrochronological studies	5
2.	Volume table preparation. Application of different sampling methods	3
3.	Quantification of regeneration and stand establishment	2
4.	Measurement of crown density and crown ratios	2
5.	Crown profiling of trees and stand	2
6.	Dendrochronological studies	2
	Total	16

I. Course Title : Silvicultural Practices

II. Course Code : SAF 503

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint the students with the advanced silvicultural practices in forestry with particular reference to commercial and short rotation forestry.

V. Theory

Unit I

Sivilculture under changing context of forestry- sivilculture and ecosystem management, stand dynamics, silvicultural practices for pure and mixed stand, even aged and uneven aged stand – silvicultural practices for changing climatic conditions.

Unit II

Silvicultural practices for natural and artificial regeneration – Ecology of regeneration, forest site management- enrichment of site – quality classes and site index models – stand density – spacing and tree growth – forest vegetation management – techniques for early stand growth- tending operations. Biomass allocation: belowground and aboveground. Changing trends in adoption of silvicultural systems.

Unit III

Stand development – stages- crown dynamics, Crown Competition factor, Maximum crown area, thinning – pruning – response of trees and impact on wood quality, salvage cutting – improvement felling and enrichment planting – management of weeds, Invasive weeds in forests, Silvicultural practices for short rotation forestry-coppice forestry, Continuous cover forestry.

Unit IV

Site specific selection of tree species. Precision silviculture –silvicultural practices for important fast growing trees and bamboos of India- *Populus species*, *Neolamarkia cadamba*, *Eucalyptus* sp., *Casuarina* sp.,*Tectona grandis*, *Melia dubia*, *Dalbergia sissoo, Gmelina arborea, Leucaena leucocephala, Ailanthus excelsa, Azadirachta indica, Swietenia macrophylla, Dendrocalamus* sp., *Bambusa* sp., – Mechanization of silvicultural practices.

VI. Practical

- Visit to different forest sites to study the influence of site factors on composition;
- Determination of site quality;
- Studies on stand structure and composition of different forest types;
- Practicing pruning and its impact on wood quality;
- Characterizing methods of thinning;
- Working out intensity of thinning;
- Study of stand densities in natural forest stand and plantation stand;
- Afforestation techniques, Wood management techniques for forest tree crops;
- Planning and designing a tree planting programme;
- Exercise on precision silviculture practices;
- Exercise on mechanized silvicultural practices.

VII. Suggested Reading

Daniel TW, Helms JA and Baker FS. 1979. *Principles of Silviculture*. McGraw-Hill Book Company.

Julius E. 1992. *Plantation Forestry in the Tropics*. Oxford University Press.

Khanna LS. 1996. *Principle and Practice of Silviculture*. International Book Distributors.

Khanna LS. 2015. *Theory and Practice of Indian Silviculture Systems*. Bio-Green Publisher.

Lamprecht. 1986. *Silviculture in the Tropics*-Verlag Paul Parey, Hamburg und Berlin.

Nyland RD, Laura S, Kenefic, Kimberly K, Bohn and Susan LS.2016 *Silviculture: Concepts and Applications* (III edition), Kindle Edition, USA.

Shepherd KR. 1986. *Plantation Silviculture*. Springer.

Smith DM, Larson BC, Ketty MJ and Ashton PMS. 1997. *The Practices of Silviculture- Applied Forest Ecology*. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Sivilculture under changing context of forestry- sivilculture and ecosystem management stand dynamics	01
2.	Silvicultural practices for pure and mixed stand, even aged and uneven aged stand	01
3.	Silvicultural practices for changing climatic conditions	01
4.	Silvicultural practices for natural and artificial regeneration	01
5.	Ecology of regeneration Forest site management- enrichment of site – quality classes	01
6.	Site index models – stand density – spacing and tree growth – forest vegetation management – techniques for early stand growth-tending operations	02
7.	Biomass allocation: belowground and aboveground	01
8.	Changing trends in adoption of silvicultural systems	01
9.	Stand development – stages- crown dynamics,site specific selection of tree species. Precision silviculture	01
10.	Crown Competition factor, Maximum crown area	01
11.	Thinning-pruning – response of trees and impact on wood quality, salvage cutting – improvement felling and enrichment planting	01
12.	Management of weeds, Invasive weeds in forest. Mechanization of silvicultural practices.	01
13.	Silvicultural practices for short rotation forestry- coppice forestry, Continuous cover forestry	01
14.	Precision silvicultural practices for important fast growing trees and bamboos of India- *Populus species*, *Neolamarkia cadamba*, *Eucalyptus* sp., *Casuarina* sp., *Tectona grandis*, *Melia dubia*, *Dalbergia sissoo*, *Gmelina arborea*, *Leucaena leucocephala*, *Ailanthus excelsa*, *Azadirachta indica*, *Swetenia macrophylla*, *Dendrocalamus* sp. and *Bambusa* sp.	03
	Total	17
	Practical	
1.	Visit to different forest sites to study the influence of site factors on composition, Determination of site quality; Studies on stand structure and composition of different forest types	3
2.	Practicing pruning and its impact on wood quality; Characterizing methods of thinning; Working out intensity of thinning	3
3.	Study of stand densities in natural forest stand and plantation stand, Afforestation techniques	3
4.	Wood management techniques for forest tree crops	2
5.	Planning and designing a tree planting programme	2
6.	Exercise on precision silviculture practices. Exercise on mechanized silvicultural practices	3
	Total	16

I. Course Title : Agroforestry Systems

II. Course Code : SAF 504

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the concept of agroforestry as a sustainable land use including diagnosis and design methodologies; overview of agroforestry and case studies.

V. Theory

Unit I

Agroforestry: objectives, importance, potentials and limitations for implementations. Land capability classification and land evaluation. Basis of classification of agroforestry systems and principles, indigenous *vs.* exotic, intraspecific variations, crown architecture of tropical/ temperate trees. Ideotype concept for selection of multipurpose trees. Nitrogen fixing trees. Overview and case studies of different agroforestry systems.

Unit II

Structural and functional attributes of agroforestry systems, shifting cultivation, taungya system, multiple and mixed cropping, alley cropping, silvopastoral systems, shelter-belts and windbreaks, energy plantations and home gardens.

Unit III

Role of trees in soil productivity and conservation– micro-site enrichment- litter and fine root dynamics, Nitrogen fixation and nutrient pumping. Soil productivity and management in agroforestry.

Unit IV

Community forestry and social forestry, linear strip plantations.

Unit V

Trends in agroforestry systems research and development, Diagnosis and Design –PRA-RRA tools in agroforestry problem diagnosis.

Unit VI

Climate Change mitigation and adaptation through agroforestry- climate negotiations- LULUCF- agroforestry options.

VI. Practical

- Survey and analysis of land use systems in the adjoining areas;
- Study of tree crown architecture;
- Design and plan of suitable models for improvement;
- PRA-RRA tools in agroforestry problem diagnosis.

VII. Suggested Reading

Buck LE, Lassoie, Fernandes ECM 1999. *Agroforestry in Sustainable Agri. Systems*. CRC Press.

Kumar BM and Nair PKR. 2006. *Tropical Homegardens: A Time-Tested Example of Sustainable Agroforestry*. Springer publication.

Kumar BM and Nair PKR. 2013. *Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges (Advances in Agroforestry)*. Springer publication.

Nair PKR and Latt 1998. *Directions in Tropical Agroforestry Research*. Kluwer.

Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer Academic Pub.
Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*. ICRAF.
Peter Huxley. 1999. *Multiple Cropping with Woody and Non-Woody Plants*. John Wiley and Sons Ltd, Oxford, United Kingdom.
Tejwani KG. 1994. *Agroforestry in India*. Oxford & IBH Publishing Co. Pvt Ltd.
Thampan PK. 1993. *Trees and Tree Farming*. Peekay Tree Crops Development Foundation.
Young A. 1997. *Agroforestry for Soil Management*. CABI.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Agroforestry: objectives, importance, potentials and limitations for implementations	02
2.	Land capability classification and land evaluation	02
3.	Basis of classification of agroforestry systems and principles	01
4.	Indigenous vs. exotic, intraspecific variations, crown architecture of tropical/ temperate trees	02
5.	Ideotype concept for selection of multipurpose trees, N fixing trees	01
6.	Overview and case studies of different agroforestry systems	04
7.	Structural and functional attributes of agroforestry systems, shifting cultivation, taungya system, multiple and mixed cropping, alley cropping, silvopastoral systems, shelter-belts and windbreaks, energy plantations and homegardens	06
8.	Role of trees in soil productivity and conservation-micro-site enrichment- litter and fine root dynamics, N fixation and nutrient pumping	04
9.	Soil productivity and management in agroforestry	02
10.	Community forestry and social forestry, linear strip plantations	02
11.	Trends in agroforestry systems research and development	01
12.	Diagnosis and Design –PRA-RRA tools in agroforestry problem diagnosis	02
13.	Climate Change mitigation and Adaptation through agroforestry-climate negotiations- LULUCF- agroforestry options	03
	Total	32
	Practical	
1.	Survey and analysis of land use systems in the adjoining areas.	5
2.	Study of tree crown architecture.	3
3.	Design and plan of suitable models for improvement.	4
4.	PRA-RRA tools in agroforestry problem diagnosis.	4
	Total	16

I. Course Title : Interactions In Agroforestry Systems

II. Course Code : SAF 505

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge to the students regarding tree-crop interaction,their quantification and techniques to neutralize the negative tree- crop interactions.

V. Theory

Unit I

Tree-crop interphase- biological factors affecting form and function in woody and non-woody plant mixtures. Nature and types of interactions- positive and negative, aboveground and belowground interactions- competition, complementarity in resource sharing.

Unit II

Method for quantifying interactions, principles of resource capture and utilization of light and water, nutrition and space. Tree-soil-crop interactions- nitrogen fixing trees interactions in agroforestry. Allelopathy. Use of radioisotopes in tree-crop interaction studies. Root distribution of trees and crops-competition and/ orcomplementarity. Animal-tree-crop interaction.

Unit III

Management options to neutralize negative (competitive) interactions, tree husbandry practices for alleviating competition- tree density manipulation, pruning, mixture of trees and herbaceous crops.

VI. Practical

- Different methods for quantifying interactions;
- Studies on allelopathy;
- Effect, microclimate modifications, different plant mixtures, tree-soil-crop interactions;
- Estimation of Land Equivalent Ratio, Estimation of competition indices;
- Measurement and interpretation of light interception in agroforestry systems;
- Interpretation of yield responses to shelter, soil water and drainage measurement, transpiration measurement, quantifying root distribution.

VII. Suggested Reading

Avery MA, Cannel MGR and Ong CK. 2005. *Biophysical Research for Asian Agroforestry*. Oxford and IBH Publishing Co. Pvt. Ltd.

Mac Dicken, KG and Vergara NT. 1989. *Agroforestry-classification and Management*.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer Academic Pub.

Ong CK and P Huxley. 2002. *Tree-Crop Interactions- A Physiological approach*, CAB International.

Patra AK. 2013. *Agroforestry-Principles and Practices*. New India Publishing AGENCY, New Delhi (India).

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Tree-crop interphase- biological factors affecting form and function in woody and non-woody plant mixtures	02
2.	Nature and types of interactions- positive and negative, aboveground and belowground interactions- competition, complementarity in resource sharing	02
3.	Methodforquantifyinginteractions	01
4.	Principlesof resource capture and utilization of light and water, nutrition and space	02

Sr. No	Topic	No. of Lecture(s)
5.	Tree-soil-crop interactions- nitrogen fixing trees interactions in agroforestry systems	02
6.	Allelopathy. Use of radioisotopes in tree-crop interaction studies	02
7.	Root distribution of trees and crops-competition and/ or complementarity	02
8.	Animal-tree-crop interaction	01
9.	Management options to neutralize negative interactions – management of competitive interactions in agroforestry, tree husbandry	01
10.	Practices for alleviating competition- tree density manipulation, pruning, mixture of trees and herbaceous crops	02
	Total	17

Practical

1.	Different methods for quantifying interactions	2
2.	Studies on allelopathy	2
3.	Effect, microclimate modifications, different plant mixtures, tree-soil-crop interactions	4
4.	Estimation of Land EquivalentRatio, Estimation of competition indices, Measurement and interpretation of light interception in agroforestry systems	4
5.	Interpretation of yield responses to shelter, soil water and drainage emeasurement, transpiration measurement, quantifying root distribution	4
	Total	16

I. Course Title : Modern Nursery Technologies

II. Course Code : SAF 506

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge and develop understanding about modern nursery techniques for mass production of quality planting stock using sexual and asexual propagation techniques.

V. Theory

Unit I

Introduction and importance of nursery. Types of nurseries-temporary and permanent, bare root, containerized and clonal nursery. Bare root nursery- nursery soil and water management, bed preparation, pre-sowing seed treatments, seed sowing and intermediate operations, viz., pricking, watering, fertilization, weeding and hoeing.

Unit II

Physiology and nursery environment interaction affecting seedling growth. Root culturing techniques. Containerized nursery—type and size of containers including root trainers, selection of growing medium. Types of green house and mist chamber for propagation.

Unit III

Vegetative propagation – importance, selection of superior genotypes, Advanced methods of propagation, containers, growing media, fertilizers, sanitation and management in vegetative propagation. Special requirement for clonal propagation. Propagation Structures and Management.

Unit IV

Clonal propagation: miniclonal and micro cuttings technology. Vegetative propagation of bamboos and canes. Factors affecting rooting of cuttings. Lifting windows. Important forest nursery pests and diseases and their management. Seedling quality assessment, grading, packaging, storing and transportation.

VI. Practical

- Introduction and identification of modern equipments and tools used in nursery;
- Pre-sowing seed treatments;
- Preparation of nursery beds and growing media for containerized nursery;
- Sowing of seed and other intermediate operations;
- Preparation and planting of cuttings;
- Use of vegetative propagation methods such as budding, grafting and layering;
- Miniclonal and microcutting technology;
- Use of plant bio-regulators for rooting;
- Assessment of seedling quality;
- Maintenance of nursery records. Identification of nursery insects and diseases and their control measures;
- Visit to forest nurseries;
- Nursery practices of commercially important tree species.

VII. Suggested Reading

Bhardwaj RL and Sarolia DK. 2011. *Modern Nursery Management.* Published by Agrobios Publishing. New Delhi (India).

Kumar GA and Gopikumar. 2003. *Forest Nursery and Tree Husbandry.*

Kumar V. 2012. *Nursery and Plantation Practices in Forestry.* Scientific Publishers (India).

Saini RS, Kaushik N, Kaushik RA and Godara NR. 2012. *Practical Nursery Production.* Agrobios, New Delhi (India).

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Introduction and importance of nursery,types of nurseries-temporary and permanent, bare root, containerized and clonal nursery	01
2.	Nursery soil and water management, bed preparation, pre- sowing seed treatments, seed sowing and intermediate operations, viz., pricking, watering, fertilization, weeding and hoeing	02
3.	Physiology and nursery environment interaction affecting seedling growth	01
4.	Root culturing techniques	01
5.	Containerized nursery – type and size of containers including root trainers, selection of growing medium	01
6.	Vegetative propagation – importance, selection of superior genotypes	01
7.	Advanced methods of propagation, containers, growing media, fertilizers, sanitation and management in vegetative propagation, types of green house and mist chamber for propagation.	03

Sr. No	Topic	No. of Lecture(s)
8.	Propagation structures and management	01
9.	Clonal propagation: miniclonal and micro cuttings technology, special requirement for clonal propagation	01
10.	Vegetative propagation of bamboos and canes. Factors affecting rooting of cuttings	02
11.	Lifting windows	01
12.	Important forest nursery pests and diseases and their management	01
13.	Seedling quality assessment, grading, packaging, storing and transportation	01
	Total	17

Practical

1.	Introduction and identification of modern equipments and tools used in nursery	1
2.	Pre-sowing seed treatments	1
3.	Preparation of nursery beds and growing media for containerized nursery	2
4.	Sowing of seed and other intermediate operations. Preparation and planting of cuttings	2
5.	Use of vegetative propagation methods such as budding, grafting and layering	2
6.	Miniclonal and microcutting technology	2
7.	Use of plant bio-regulators for rooting. Assessment of seedling quality	2
8.	Maintenance of nursery records. Identification of nursery insects and diseases and their control measures	2
9.	Visit to forest nurseries. Nursery practices of commercially important tree species	2
	Total	16

I. Course Title : Plantation Forestry

II. Course Code : SAF 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with various aspects of production, integrated nutrient and irrigation management and ecological factors in raising forest plantations.

V. Theory

Unit I

Role of plantation forestry in meeting the wood demand – status of plantation forestry in India and world. Purpose of plantation, factors determining scale and rate of plantation. Land suitability and choice of species. Preliminary site preparation for establishing plantation. Plantation planning, project formulation and appraisal. Planting programme, time of planting, spacing, pattern and planting methods.

Unit II

Nutritional dynamics and irrigation of plantation. Mechanization in plantation.

Protection and after care of plantation. Pruning and thinning in plantations for quality wood production. Rotation in plantation. Failures of plantations. Impact of interaction and integration of plantation forestry.

Unit III

Protective afforestation, afforestation of inhospitable sites. Plantation forestry for climate change mitigation- carbon forestry. Ecological factors and long term productivity. Sustainable yield from plantations. Case studies in plantations of Eucalyptus, Casuarina, Poplars, Acacias, Pine, Silver Oak, Gmelina, Teak, Sandal, Bamboo, etc. Production technology of energy plantations, industrial plantations. Emerging concepts in plantation forestry: mixed plantation, continuous cover forests.

VI. Practical

- Analysis of plantation problems in Asia and India;
- Preparation of plantation calendar –Preliminary arrangement for a plantation programme;
- Planting geometry and calculation of planting stock;
- Study of different cultural operations and site preparation for plantation;
- Studies on wood based industries – problems and prospects;
- Management of Eucalyptus, Casuarina, Teak, Sal, Poplar, Acacias and Bamboo plantations;
- Production technology for energy plantations. INM in plantations;
- Irrigation and plantations;
- Economics of pulpwood, timber and energy plantations. Study of mixed plantation model.

VII. Suggested Reading

Dwivedi AP. 1993. *Forestry in Indi*a. Surya Publ.

Julius E. 1982. *Plantation Forestry in the Tropic*s. Clarendon Press, Oxford.

Kumar V. 1999. *Nursery and Plantation Practices in Forestr*y. Scientific Publ.

Luna RK. 1989. *Plantation Forestry in Indi*a. International Book Distributors.

Prakash R, Chaudhari DC and Negi SS. 1998. *Plantation and Nursery Techniques of Forest Tree*s. International Book Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Role of plantation forestry in meeting the wood demand – status of plantation forestry in India and world	02
2.	Purpose of plantation, factors determining scale and rate of plantation	01
3.	Land suitability and choice of species	02
4.	Preliminary site preparation for establishing plantation	02
5.	Plantation planning, project formulation and appraisal. Planting programme, time of planting, spacing, pattern and planting methods	03
6.	Nutritional dynamics and irrigation of plantation	02
7.	Mechanization in plantation	01
8.	Protection and after care of plantation	01
9.	Pruning and thinning in plantations for quality wood production. Rotation in plantation	01
10.	Failures of plantations. Impact of interaction and integration of plantation forestry	02

Sr. No	Topic	No. of Lecture(s)
11.	Protective afforestation, afforestation of inhospitable sites	03
12.	Plantation forestry for climate change mitigation- carbon forestry	02
13.	Ecological factors and long term productivity. Sustainable yield from plantations	02
14.	Case studies in plantations of Eucalypts, Casuarina, Poplars, Acacias, Pine, Silver Oak, Gmelina, Teak, Sandal, Bamboo, etc. Wasteland plantations	04
15.	Production technology of energy plantations, Industrial plantations	02
16.	Emerging concepts in plantation forestry: mixed plantation, continuous cover forests	02
	Total	32

Practical

1.	Analysis of plantation problems in Asia and India	1
2.	Preparation of plantation calendar –Preliminary arrangement for a plantation programme	2
3.	Planting geometry and calculation of planting stock	2
4.	Study of different cultural operations and site preparation for plantation	2
5.	Studies on wood based industries – problems and prospects	2
6.	Management of *Eucalyptus, Casuarina,* Teak, Sal, Poplar, *Acacias* and Bamboo plantations	2
7.	Production technology for energy plantations	1
8.	INM in plantations. Irrigation and plantations	2
9.	Economics of pulpwood, timber and energy plantations. Study of mixed plantation model	2
	Total	16

I. Course Title : Industrial Agroforestry

II. Course Code : SAF 508

III. Credit Hours : 1+1

IV. Aim of the course

To develop skill and expertise on industrial wood production and processing technology.

V. Theory

Unit I

Role of forests in industrial sector, industrial raw material, demand and supply, indigenous and exotic industrial resources, extent of area, policy and legal issues towards industrial wood plantation. Major wood based industries in India; timber, pulp wood, plywood, matches, etc. Raw material requirements and their procurements.

Unit II

Industrial wood plantations – status in India and different states, preferred species – current plantation management and establishment, propagation and plantation technique, economics of industrial agroforestry, pest and disease management for major industrial wood species, harvesting, reduced impact logging, mechanization.

Unit III

Supply chain; definition, concept, supply chain network, logistic activities, Marketing system; marketing type and channel, price patterns of various industrial wood agroforestry plantations. Contract farming: concept and methods, contract tree farming system in India. Industrial experiences– price support system – constraints. Corporates in industrial agroforestry: International and National corporate, success stories. Corporate social responsibilities. Tree insurance.

Unit IV

Impacts of industrial agroforestry – ecological impacts; climatic, edaphic and biotic– carbon sequestration. Carbon storage potential of industrial agroforestry and carbon trading mechanism of industrial agroforestry, socio-economic impacts–clean development mechanism. Certification of industrial plantations.

VI. Practical

- Study of various wood based industries;
- Study on raw material requirement and sourcing of plywood, pulp and paper, matchwood, timber processing;
- Biomass power generation industries;
- Value addition technology of various wood products;
- Industrial wood plantations – economics and impact assessment.

VII. Suggested Reading

Cosasalter C and C Pye-Smith. 2003. *Fast Wood Forestry – Myths and Realities*. CIFOR. Bogor, Indonesia. 50p.

Mehta T. 1981. *A Hand Book of Forest Utilization*. International Book Distributors, Dehradun.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer Academic publishers.

Parthiban KT, Umarani R, Umesh Kanna S, Sekar I, Rajendran P and Durairasu P. 2014. *Industrial Agroforestry: Perspectives and Prospectives*. Scientific Publishers.

Tejwani KG. 1994. *Agroforestry in India*. Oxford and IBH publishing Co., New Delhi.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Role of forests in industrial sector, industrial raw material, demand and supply, indigenous and exotic industrial resources, extent of area, policy and legal issues towards industrial wood plantation	03
2.	Major wood based industries in India; timber, pulp wood, plywood, matches, etc. raw material requirements and their procurements	01
3.	Industrial wood plantations – status in India and different states, preferred species – current plantation management and establishment, propagation and plantation technique, economics of industrial agroforestry	02
4.	Pest and disease management for major industrial wood species, harvesting, reduced impact logging, mechanization	01
5.	Supply chain; definition, concept, supply chain network, logistic activities	01

Sr. No	Topic	No. of Lecture(s)
6.	Marketing system; marketing type and channel, price patterns of various industrial wood agroforestry plantations	02
7.	Contract farming; concept and methods, contract tree farming system in India	01
8.	Industrial experiences– price support system – constraints. Corporates in industrial agroforestry; International and National corporate, success stories. Corporate social responsibilities. Tree insurance	01
9.	Impacts of industrial agroforestry – ecological impacts; climatic, edaphic and biotic– carbon sequestration	01
10.	Carbon storage potential of industrial agroforestry and carbon trading mechanism of Industrial agroforestry, socio-economic impacts–clean development mechanism	02
11.	Certification of industrial plantations	01
	Total	16

Practical

1.	Industrial wood plantations – economics and impact assessment	3
2.	Study on raw material requirement and sourcing of plywood, pulp and paper, matchwood, timber processing	4
3.	Biomass power generation industries	3
4.	Value addition technology of various wood products	3
5.	Study of various wood based industries	3
	Total	16

I. Course Title : Climate Change and Conservation Silviculture

II. Course Code : SAF 509

III. Credit Hours : 2+0

IV. Aim of the course

To understand the scenario of climate change and international treaties on climate change, adaptive silviculture for climate change mitigation, silviculture for conservation of ecosystems.

V. Theory

Unit I

Global climate change-factors involved, green house gases, potential threats, global carbon cycle and C-budget, carbon sequestration. Forests and climate change: Forest responses and vulnerabilities to climate change mitigation.Status of forests in global climate change. Harnessing Forests for Climate Change Mitigation, International climate negotiation, UNFCCC, IPCC, CoP:LULUCF, REDD++ and CDM.

Unit II

Silviculture and sustainability-criteria and indicators for sustainable plantation forestry in India-CIFOR guidelines. Silvicultural and stand management strategies for carbon sink maximization and source minimization. Adaptive silviculture for climate change.

Unit III

Disturbance- natural and anthropogenic, short and long term impacts and their implications. Fire loss estimation in forests. Deforestation and degradation trends at global, national and regional levels. Mega development projects, Road widening projects and conservation of native and threatened species, management and rehabilitation plans.

Unit IV

Impacts of 'No Green Felling' on stand productivity and health. Restoration forestry-silvicultural treatments for habitat restoration, catchment area treatments, enrichment planting, Analog forestry for site productivity and carbon value. Expanding forest and tree cover area- TOF sector in India.

Unit V

Role of canopy in regulating functional inputs to stand: canopy and forest continuum, Continuous Cover Forestry. Silviculture of old growth stands and sacred grooves-their ecological significance and biodiversity values. Carbon sequestration potential of Trees Outside forests (TOFs), homegardens and urban forests.

VI. Suggested Reading

Anderson P and Palik B. 2011. *Silviculture for Climate Change.* U.S. Department of Agriculture, Forest Service, Climate Change Resource Center.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Global climate change-factors involved, green house gases, potential threats, global carbon cycle and C-budget, carbon sequestration	02
2.	Forests and climate change: Forest responses and vulnerabilities to climate change mitigation	02
3.	Status of forests in global climate change.Harnessing Forests for Climate Change Mitigation International climate negotiation, UNFCCC, IPCC, CoP:LULUCF, REDD++ and CDM	03
4.	Silviculture and sustainability-criteria and indicators for sustainable plantation forestry in India-CIFOR guidelines	03
5.	Silvicultural and stand management strategies for carbon sink maximization and source minimization	03
6.	Adaptive silviculture for climate change	01
7.	Disturbance- natural and anthropogenic, short and long term impacts and their implications. Fire loss estimation in forests	02
8.	Deforestation and degradation trends at global, national and regional levels	02
9.	Mega development projects, Road widening projects and conservation of native and threatened species, management and rehabilitation plans	02
10.	Impacts of 'No Green Felling' on stand productivity and health	01
11.	Restoration forestry-silvicultural treatments for habitat restoration, catchment area treatments, enrichment planting	02

Sr. No	Topic	No. of Lecture(s)
12.	Analog forestry for site productivity and carbon value	01
13.	Expanding forest and tree cover area- TOF sector in India	02
14.	Role of canopy in regulating functional inputs to stand,: canopy and forest continuum, Continuous Cover Forestry	02
15.	Silviculture of old growth stands and sacred grooves- their ecological significance and biodiversity values	02
16.	Carbon sequestration potential of Trees Outside forests (TOFs), homegardens and urban forests	02
	Total	32

I. Course Title : Trees and Shrubs for Agroforestry

II. Course Code : SAF 510

III. Credit Hours : 1+1

IV. Aim of the course

To make students familiar with trees and shrubs (fruit, fodder and small timber) suitable for agroforestry.

V. Theory

Unit I

Introduction, importance of woody elements in agroforestry systems, their role in biomass production. Suitability of species for different purposes. Multipurpose trees in agroforestry systems. Fodder from trees/ shrubs and their nutritive value, propagation techniques.

Unit II

Role of nitrogen fixing trees/ shrubs. Choice of species for various agro-climatic zones for the production of timber, fodder, fuel wood, fibre, fruits, medicinal and aromatic plants. Generic and specific characters of trees and shrubs for agroforestry.

Unit III

Fruit crop and small timber trees and their need and relevance in agroforestry, trees suitable for various assemblage and their planting plan in different agroclimatic zones and agroforestry system. Intercropping in fruit orchards like Apple, Walnut, Jack fruit, Mango, Sapota, Pomegranate, Orange, Citrus, Guava, etc. Modification in tending and pruning operations and canopy management. Fertility management, yield and quality improvement.

VI. Practical

- Field survey and acquaintance with specialized features of trees, shrubs and fruit species and varieties for Agroforestry;
- Planting plans including wind breaks;
- Training and pruning of forest trees, shrubs and fruit trees for enhancing production in agroforestry system.

VII. Suggested Reading

Dwivedi AP. 1992. *Agroforestry: Principles and Practices*. Oxford & IBH.
Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer.
Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer.

Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*. ICRAF.
Srivastava KK. 2007. *Canopy Management of Fruit Crops*, IBD.
Thampan PK. 1993. *Trees and Tree Farming*. Peekay Tree Crops Development Foundation.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction, importance of woody elements in agroforestry systems, their role in biomass production	02
2.	Suitability of species for different purposes. Multipurpose trees in agroforestry systems	02
3.	Fodder from trees/ shrubs and their nutritive value, propagation techniques	02
4.	Role of nitrogen fixing trees/ shrubs	01
5.	Choice of species for various agroclimatic zones for the production of timber, fodder, fuel wood, fibre, fruits, medicinal and aromatic plants	02
6.	Generic and specific characters of trees and shrubs for agroforestry	01
7.	Fruit crop and small timber trees and their need and relevance in Agroforestry	01
8.	Trees suitable for various assemblage and their planting plan in different agroclimatic zones and agroforestry system	02
9.	Intercropping in fruit orchards like Apple, Walnut, Jack fruit, Mango, Sapota, Pomegranate, Orange, Citrus, Guava, etc.	02
10.	Modification in tending and, pruning operations and canopy management, fertility management, yield and quality improvement	02
	Total	17
	Practical	
1.	Field survey and acquaintance with specialized features of trees, shrubs and fruit species and varieties for Agroforestry	6
2.	Planting plans including wind breaks	4
3.	Training and pruning of tree, shrubs and fruit trees for enhancing production in agroforestry system	6
	Total	16

I. Course Title : Economics of Agroforestry Systems

II. Course Code : SAF 511

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with principles of economics and use of economic tools in appraisal of the agroforestry systems. Evaluation of ecosystem services from agroforestry- economic and ecological aspects of agroforestry.

V. Theory

Unit I

Basic principles of economics applied to agroforestry. Financial measures.

Quantification and valuation of inputs and outputs- direct and indirect methods.

Unit II

Optimization techniques-Planning, budgeting and functional analysis. Role of time, risk and uncertainty in decision making. Agroforestry budgeting. Risk analysis, re-assessment.

Unit III

Financial and socio-economic analysis of agroforestry projects. Principles of financial management and harvesting, post harvest handling, value addition, marketing of agroforestry products including benefit sharing.

Unit IV

Valuation of ecosystem services in agroforestry and payment for ecosystem systems. Bankable agroforestry projects, incentives, tree insurance, etc. Certification process in agroforestry based carbon projects, carbon finance, etc.

VI. Practical

- Exercises on agroforestry production relationships;
- Preparation of agroforestry based enterprise, partial and complete budgets;
- Application of various methods in formulation and appraisal of agro-forestry projects;
- Case studies on harvesting, post harvest management and marketing of agro-forestry products;
- Valuation of ecosystem services in agroforestry and payment for ecosystem services.

VII. Suggested Reading

Alavalapati JRR and Mercer D Evan. 2004 *Valuing Agroforestry Systems: Methods and Applications*. Kluwer Academic Publishers.

Kant S and Janaki A. 2014. *Handbook of Forest Resource Economics*. Publisher: Routledge

Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer Academic Publishers.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer Academic Publishers.

Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*. ICRAF.

Sullivan Gregory M, Susan Hoke M and Jefferson M. Fox (editors). 1992. *Financial and Economic Analyses of Agroforestry Systems. Proceedings of a workshop held in Honolulu. Hawaii. USA. July* 1991. Paia, Ill: Nitrogen Fixing Tree Association.

Thampan PK. 1993. *Trees and Tree Farming*. Peekay Tree Crops Development Foundation.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Basic principles of economics applied to agroforestry	03
2.	Financial measures	02
3.	Quantification and valuation of inputs and outputs- direct and indirect methods	03
4.	Optimization techniques-Planning, budgeting and functional analysis	03
5.	Role of time, risk and uncertainty in decision making	02
6.	Agroforestry budgeting, risk analysis, re-assessment	03
7.	Financial and socio-economic analysis of agroforestry projects	03
8.	Principles of financial management and harvesting, post-harvest handling, value addition, marketing of agroforestry products including benefit sharing	04

Sr. No	Topic	No. of Lecture(s)
9.	Valuation of ecosystem services in agroforestry and payment for ecosystem systems	03
10.	Bankable agroforestry projects, incentives, tree insurance, etc.	03
11.	Certification process in agroforestry based carbon projects, carbon finance, etc.	03
	Total	32

Practical

1.	Exercises on agroforestry production relationships	3
2.	Preparation of agroforestry based enterprise, partial and complete budgets	4
3.	Application of various methods in formulation and appraisal of agro-forestry projects	3
4.	Case studies on harvesting, post harvest management and marketing of agro-forestry products	3
5.	Valuation of ecosystem services in agroforestry and payment for ecosystem services	3
	Total	16

I. Course Title : Tree Seed Technology

II. Course Code : SAF 512

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and to develop understanding about tree seed development, harvesting, processing, storage, dormancy, germination of tropical, sub-tropical and temperate species, their testing and certification.

V. Theory

Unit I

Introduction, trends and development in tropical, sub-tropical and temperate forestry and their influence on seed demand. Seed problems, limiting factors in tree propagation and afforestation.

Unit II

Reproductive biologyof seed plants – development and maturation of seed bearing organs and seeds – morphology of fruit and seed – seed dispersal – ecological fruit and seed types- seasonality and periodicity of flowering and fruiting – reproductive age – influence of external factors on seed production. Seed structure and chemical composition – development and maturation – germination – breakdown of storage products – endogenous hormonal regulation – effect of stimulators and inhibitors– dormancy – its causes and breakage specific problems of seeds of woody plants.

Unit III

Determining maturity indices. Factors influencing choice of collection methods.

Methods of seed collection and processing. Storage methods – loss of viability during storage. Dormancy and pre-treatment. Germination and seedling establishment and seed testing techniques.

Unit IV

Quality seed production technologies – seed certification.

Unit V

Eco-physiological role of seed storage. Classification of seed storage potential. Factors affecting seed longevity. Pre-storage treatment. Physiological change during ageing. Storage of orthodox, recalcitrant and intermediate seeds, Fumigation and seed treatment.

VI. Practical

- Identification of forest seeds;
- Seed sampling, different storage methods, Seed quality testing-purity, viability and germination, collection and processing of seeds/ fruit;
- Tests of viability, viz., cutting, hydrogen peroxide, excised embryo, tetrazolium, seed health testing primarily to the presence or absence of disease-causing organisms such as fungi, bacteria, virus and animal pests, recording, calculation and use of results of seed treatment.

VII. Suggested Reading

Baldwin HI. 1942. *Forest Tree Seed of the North Temperate Regions*. Periodical Experts Book Agency, Delhi.

Bedell PE. 1998. *Seed Science and Technology: Indian Forestry Species*. Allied Publisher Limited.

Chin HF and Roberts EH. 1980. *Recalcitrant crop seeds*. Tropical Press Sdn. Bhd. Malaysia.

Dutta M and Saini GC. 2010. *Forest Tree Improvement and Seed Technology*.

Hong TD and Ellis RH. 1996. *A protocol to determine seed storage behaviour*. IPGRI Technical Bulletin No. 1. (J. M. M. Engels and J. Toll, vol. Eds.) International Plant Genetic Resources Institute, Rome, Italy.

ISTA. 1993. *International Rules for Seed Testing*. International Seed Testing Association, Zurich, Switzerland.

Khullar P. *et al*. 1992. *Forest Seed*. ICFRE, New Forest, Dehra Dun.

Leadem CL. 1984. *Quick Tests for Tree Seed Viability*. B.C. Ministry of Forests and Lands, Canada.

Schmidt L. 2000. *Guide to handling of tropical and subtropical forest seed*. DANIDA Forest Seed Centre, Denmark.

Umarani R and Vanangamudi K. 2004. *An Introduction to Tree Seed Technology*. IBD, Dehradun.

Vanangamudi K. 2007. *Advances in Seed Science and Technology*: (Vol. 1. to 5).

Willan RL. 1985. *A guide to forest seed handling*. FAO Forestry Paper 20/2, DANIDA Forest Seed Centre, Denmark and FAO, Rome.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Introduction, trends and development in tropical, sub-tropical and temperate forestry and their influence on seed demand	03
2.	Seed problems, limiting factors in tree propagation and afforestation	01
3.	Reproductive biology of seed plants – development and maturation of seed bearing organs and seeds	03
4.	Morphology of fruit and seed – seed dispersal – ecological fruit and seed types	02

Sr. No	Topic	No. of Lecture(s)
5.	Seasonality and periodicity of flowering and fruiting – reproductive age – influence of external factors on seed production	02
6.	Seed structure and chemical composition – development and maturation – germination – breakdown of storage products – endogenous hormonal regulation – effect of stimulators and inhibitors	03
7.	Dormancy – its causes and breakage, specific problems of seeds of woody plants	02
8.	Determining maturity indices	01
9.	Factors influencing choice of collection methods. Methods of seed collection and processing, storage methods – loss of viability during storage	02
10.	Dormancy and pre-treatment. Germination and seedling establishment and seed testing techniques	02
11.	Quality seed production technologies – seed certification	03
12.	Eco-physiological role of seed storage. Classification of seed storage potential. Factors affecting seed longevity	03
13.	Pre-storage treatment. Physiological change during ageing	02
14.	Storage of orthodox, recalcitrant and intermediate seeds. Fumigation and seed treatment	03
	Total	32

Practical

1.	Identification of forest seeds.	3
2.	Seed sampling, different storage methods, Seed quality testing-purity, viability and germination, collection and processing of seeds/ fruit	6
3.	Tests of viability, viz., cutting, hydrogen peroxide, excised embryo, tetrazolium, seed health testing primarily to the presence or absence of disease-causing organisms such as fungi, bacteria, virus and animal pests, recording, calculation and use of results of seed treatment.	7
	Total	16

I. Course Title : Nutrient and Weed Management in Oduction Forestry

II. Course Code : SAF 513

III. Credit Hours : 1+1

IV. Aim of the course

To make students to understand the concepts of nutrients and their management, weeds and their management in nurseries and plantations.

V. Theory

Unit I

History of nutrient management in forest nurseries and plantations. Essential nutrient elements and their deficiency. Mechanism of nutrient uptake by plants, functions and translocation/ interactions. Concept of nutrient availability.

Unit II

Climatic and soil conditions causing micronutrient deficiencies in plants. Occurrence and treatment of micronutrient disorders. Evaluation of soil for the supply of micronutrient. Rare and non-essential elements.

Unit III

Technology and use of complex liquid and suspension fertilizers. Fertilizer use efficiency. Biological nitrogen fixation and bio-fertilizers. Farm yard manure and other organic fertilizers. Mycorrhizal associations and their significance. Economic implications of nutrient management. Importance of renewable wastes and their recycling.

Unit IV

Principles of weed control. Methods of weed control-cultural, biological, mechanical and chemical. Herbicide/ weedicide classification, properties and their application.

VI. Practical

- Methods of soil and plantanalysis.
- Preparation of nutrient solutions.
- Practical application of fertilizers;
- Study of fertilizer response and diagnosis of deficiency symptoms.
- Fertilizer testing and pot experiments;
- Nursery inoculation techniques of bio-fertilizers;
- Methods of application of formulated products-seed treatment, root dip, suckers treatment, soil application, foliar application and combination of different methods;
- Important weeds in forest nurseries and plantations. Control of weeds.

VII. Suggested Reading

Allen V and Barker. 2007. *Handbook of Plant Nutrition*. Pilbeam London.

Gupta OP. 2011. *Modern Weed Management*. Agrobios, New Delhi (India).

Kumar D, Chowdhary S and Sharma R. 2011. *Weed Management: Principles and Practices*. Narendra Publishing House.

Rajaram C. 2012. *Hand book of Plant Nutrition*. Neha Publishers and Distributors.

Rammoorthy and Subbian P. 2012. *Weed Management*. Agrotech Publishing Academy, Udaipur (India).

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	History of nutrient management in forest nurseries and plantations	01
2.	Essential nutrient elements and their deficiency	01
3.	Mechanism of nutrient uptake by plants, functions and translocation/ interactions	01
4.	Concept of nutrient availability	01
5.	Climatic and soil conditions causing micronutrient deficiencies in plants	01
6.	Occurrence and treatment of micronutrient disorders	01
7.	Evaluation of soil for the supply of micronutrient. Rare and non-essential elements	01
8.	Technology and use of complex liquid and suspension fertilizers	01
9.	Fertilizer use efficiency	01
10.	Biological nitrogen fixation and bio-fertilizers	01
11.	Farm yard manure and other organic fertilizers	01
12.	Mycorrhizal associations and their significance	01
13.	Economic implications of nutrient management	01

Sr. No	Topic	No. of Lecture(s)
14.	Importance of renewable wastes and their recycling	01
15.	Principles of weed control	01
16.	Methods of weedc ontrol-cultural, biological, mechanical and chemical	01
17.	Herbicide/ weedicide classification, properties and their application	01
	Total	17

Practical

1.	Methods of soil and plant analysis	2
2.	Preparation of nutrient solutions	2
3.	Practical application of fertilizers	1
4.	Study of fertilizer response and diagnosis of deficiencysymptoms	2
5.	Fertilizer testing and pot experiments	2
6.	Nursery inoculation techniques of bio-fertilizers.	2
7.	Methods of application of formulated products-seed treatment, root dip, suckers treatment, soil application, foliar application and combination of different methods.	3
8.	Important weeds in forest nurseries and plantations. Control of weeds	2
	Total	16

I. Course Title : Crops and Live Stock Management in Agroforestry

II. Course Code : SAF 514

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge on interactions between tree and live stock including their management, principles of crops and fodder production in agroforestry.

V. Theory

Unit I

Choice of inter-crops for different tree species, sowing and planting techniques. Planting patterns, crop geometry, nutrient requirements, and weed management. Management of fodder tree species, thinning, lopping, pruning. Ecological and socio-economic interactions.

Unit II

Role of tree architecture and its management on system's productivity. Production potentials of fodder based agroforestry systems in different agro-climatic conditions and crop combinations. Importance of cattle, sheep and goat vis-à-vis agro-forestry systems. Feed and fodder resources in agro-forestry systems and live stock management.

Unit III

Nutrient analysis of forages derived from fodder trees/ shrubs. Nutrient requirement for various livestock and their ration computation with agroforestry forages and tree leaves. Forage and tree leaves preservation.

Unit IV

Calendars for forage crop production in agro-forestry systems including lopping schedules. Optimization of animal production. Animal products technology and marketing.

Unit V

Integrated Agroforestry Farming System.

VI. Suggested Reading

Bran Powell. 2017. *Livestock Production and Management.* L & K Education.

Kundu SS, Dagar JC, Prakash O, Chaturvedi and Sirohi SK. 2008. *Environment, Agroforestry and Livestock Management.*

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Choice of inter-crops for different tree species, sowing and planting techniques	03
2.	Planting patterns, crop geometry, nutrient requirements, and weed management	03
3.	Management of fodder tree species, thinning, lopping, pruning	02
4.	Ecological and socio-economic interactions	02
5.	Role of tree architecture and its management on system's productivity	02
6.	Production potentials of fodder based agroforestry systems in different agro climatic conditions and crop combinations	02
7.	Importance of cattle, sheep and goat vis-à-vis agro-forestry systems	02
8.	Feed and fodder resources in agro-forestry systems and live stock management	02
9.	Nutrient analysis of forages derived from fodder trees/ shrubs	02
10.	Nutrient requirement for various livestock and their ration computation with agroforestry forages and tree leaves	02
11.	Forage and tree leaves preservation	02
12.	Calendars for forage crop production in agro-forestry systems including lopping schedules	02
13.	Optimization of animal production. Animal products technology and marketing	03
14.	Integrated Agroforestry Farming System	03
	Total	32

Course Title with Credit Load
Ph.D. (Forestry) in Silviculture and Agroforestry

Course Code		Course Title	Credit Hours
		Major Courses	
SAF 601*	I	Quantitative Silviculture	2+1
SAF 602*	II	Agroforestry Research and Management	2+1
SAF 603	I	Forest Stand Dynamics	1+0
SAF 604	II	Productivity and Evaluation of Agroforestry Systems	2+1
SAF 605	I	Forest Stand Management Techniques	1+1
SAF 606	II	Agroforestry for Ecosystem Services and Environmental Benefits	2+0
SAF 607	I	Plantation Forest Productivity	1+1
SAF 608	II	Restoration Forestry	1+0
SAF 609	I	Regeneration Silviculture	2+1
SAF 610	II	Forest Soil Management	1+1
SAF 611	I	Agroforestry for Sustainable Agriculture	1+0
		Minor Courses	
		Courses from Forest Biology and Tree Improvement or Forest Products and Utilization	06
		Supporting Courses	
FOR 610*	I	Research Methodology in Forestry	2+1
FOR 611	II	Research and Publication Ethics	1+1
SAF 691*	I/ II	Doctoral Seminar	1+0
SAF 692*	I/ II	Doctoral Seminar	1+0
	ii)	Thesis Research	
SAF 699		Doctoral Research	0+75

*Compulsory Core Courses

Course Contents
Ph.D. (Forestry) in Silviculture and Agroforestry

I. Course Title : Quantitative Silviculture

II. Course Code : SAF 601

III. Credit Hours : 2+1

IV. Aim of the course

To educate students with regard to forest stand growth and yield, quantitative techniques used for evaluating site quality, measuring stand density, predicting forest growth and yield.

V. Theory

Unit I

Principles of tree and stand growth and yield. Habitat types; site quality; site index.

Growth functions – empirical, exponential, allometry and Backman's growth functions. Growth pattern and growth increment curve. Growth cycle and phases. Quantifying site quality: Methods – tree and stand height data, periodic height growth. Techniques – guide curves, difference equations, parameter prediction.

Unit II

Stand density and stocking, measures of density: –3/2 power rule of self-thinning, point density, competition indices. Control of growing stock to achieve specific management objectives – growth-growing stock relations, Full site occupancy, Onset of competitive interactions. Langsaeter's hypothesis, stand density index and techniques for translating this understanding into rational density management regimes.

Unit III

Techniques: stand density management diagrams and stocking charts. Construction and use of stand density management diagrams. Designing density management regimes to suit specific management objectives.

Unit IV

Predicting growth and yield: normal and empirical yield tables, stand growth and yield equations, stand table projections. Simulation models: whole-stand models, size-class distribution models, single tree/ distance independent and distance-dependent models, process models, linkage of models at different levels. Evaluation, calibration, verification, and validation of forest growth and yield prediction systems. Introduction to existing forest growth and yield simulators.

VI. Practical

- Assessment of growth characteristics;
- Preparation of growth and increment curves;
- Site quality assessment, Stand density diagrams;
- Growth prediction models;
- Yield simulation techniques.

VII. Suggested Reading

Clutter JL, Fortson JC, Pienaar LV, Brister GH and Bailey RL. 1992. *Timber Management: A Quantitative Approach*. Krieger Publishing Company.

Davis LS and Johnson KN. 1987. *Forest Management*. 3rd Ed. McGraw-Hill.

Evans J. 1982. *Plantation Forestry in the Tropics*. Clarendon Press.

Johnson PS, Shifley SR and R. Rogers. 2009. *Self-thinning and Stand Density*. *The Ecology and Silviculture of Oaks*. CABI, Cambridge, MA.

Luna RK. 1989. *Plantation Forestry in India*. International Book distributors.

Vanclay JK. 1994. *Modeling Forest Growth and Yield: Application to Mixed Tropical Forests*. CAB International.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Principles of tree and stand growth and yield	02
2.	Habitat types; site quality; site index	02
3.	Growth functions – empirical, exponential, allometry and Backman's growth functions	03
4.	Growth pattern and growth increment curve. Growth cycle and phases	02
5.	Quantifying site quality: Methods – tree and stand height data, periodic height growth	02
6.	Techniques – guide curves, difference equations, parameter prediction	02
7.	Stand density and stocking, measures of density: –3/2 power law of self-thinning, point density, competition indices	03
8.	Control of growing stock to achieve specific management objectives – Growth-growing stock relations, Full site occupancy, Onset of competitive interactions. Langsaeter's hypothesis, stand density index and techniques for translating this understanding into rational density management regimes	03
9.	Techniques: stand density management diagrams and stocking charts. Construction and use of stand density management diagrams. Designing density management regimes to suit specific management objectives	03
10.	Predicting growth and yield: normal and empirical yield tables, stand growth and yield equations, stand table projections	03
11.	Simulation models: whole-stand models, size-class distribution models, single tree/ distance independent and distance-dependent models, process models, linkage of models at different levels	04
12.	Evaluation, calibration, verification, and validation of forest growth and yield prediction systems. Introduction to existing forest growth and yield simulators	03
	Total	32
	Practical	
1.	Assessment of growth characteristics	2
2.	Preparation of growth and increment curves	3
3.	Site quality assessment, Stand density diagrams	4
4.	Growth prediction models	3
5.	Yield simulation techniques	4
	Total	16

I. Course Title : Agroforestry Research and Management

II. Course Code : SAF 602

III. Credit Hours : 2+0

IV. Aim of the course

To teach how to refine the agroforestry systems, management practices and their integration for developing suitable agroforestry systems.

V. Theory

Unit I

Recent trends in agroforestry research and development. Agroforestry land use systems and their salient features. Research designs and analysis in agroforestry. Multi-functionality of agroforestry systems-multiplicity of products and services, food and nutritional security, livelihood security, gender related aspects. Constraints in agroforestry research – research prioritization.

Unit II

Study of systems specification, prioritizing potential interventions and technology specifications; space and time related considerations.

Unit III

Introduction to on-farm and on-station research experiments. Biomass production and allocation patterns- changes thorough agroforestry interventions.

Unit IV

Belowground dynamics- role of fine roots in agroforestry productivity. Tree husbandry practices in agroforestry for productivity optimization. Soil-site sustainability and environmental resource sharing. Site-species compatibility. Competition, predation, mutualism, commensalisms. Simulation modeling of agroforestry systems.

Unit V

Carbon and nutrient dynamics in agroforestry- carbon sequestration- carbon credits- mitigatory and adaptive roles of agroforestry in the context of climate change- climate negotiations and agroforestry.

Unit VI

Management of multifunctional agroforestry – sustainability, links with UNFCCC, UNCCD and UNCBD. Carbon conservation, sequestration, and substitution functions of agroforestry trees. Domestication of useful species and crafting market regimes for the products derived from agroforestry and ethno-forestry systems. Contract fuel wood schemes, small-scale nursery enterprises, charcoal policy reform, novel market information systems, facilitating and capacity building of farmer and farm forest associations. Climate change and reforestation incentive policies.

Unit VII

Market intelligence for agroforestry products. Agroforestry value chain models: consortia concepts. Successful case studies.

VI. Suggested Reading

Chin K Ong, Colin Black and Julia Wilson. 2015. *Tree-Crop Interactions*, 2nd Edition: Agroforestry in a Changing Climate. CAB International.

Kumar BM and Nair PKR. 2011. *Carbon Sequestration Potential of Agroforestry Systems: Oportunities and Challenges*. Springer.
Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer.
Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*. ICRAF.
Snelder DJ and Lasco RD. 2008. *Smallholder Tree Growing for Rural Development and Environmental Services*. Springer Science, Amsterdam.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Recent trends in Agroforestry research and development	02
2.	Agroforestry land use systems and their salient features. Research designs and analysis in agroforestry	02
3.	Multifunctionality of agroforestry systems – multiplicity of products and services, food and nutritional security, livelihood security, gender related aspects	02
4.	Constraints in agroforestry research – research prioritization	02
5.	Study of systems specification, prioritizing potential interventions and technology specifications; space and time related considerations	02
6.	Introduction to on farm and on station research experiments	01
7.	Biomass production and allocation patterns- changes thorough agroforestry interventions	01
8.	Belowground dynamics- role of fine roots in agroforestry productivity	02
9.	Tree husbandry practices in agroforestry for productivity optimization. Soil-site sustainability and environmental resource sharing. Site-Species compatibility	02
10.	Competition, predation, mutualism, commensalisms. Simulation modeling of agroforestry systems	02
11.	Carbon and nutrient dynamics in agroforestry- carbon sequestration - carbon credits- mitigatory and adaptive roles of agroforestry in the context of climate change- climate negotiations and agroforestry	02
12.	Management of multifunctional agroforestry – sustainability, links with UNFCCC, UNCCD and UNCBD	02
13.	Carbon conservation, sequestration, and substitution functions of agroforestry trees	02
14.	Domestication of useful species and crafting market regimes for the products derived from agroforestry and ethnoforestry systems	02
15.	Contract fuel wood schemes, small-scale nursery enterprises, charcoal policy reform, novel market information systems, facilitating and capacity building of farmer and farm forest associations	02
16.	Climate change and reforestation incentive policies	02
17.	Market intelligence for agroforestry products. Agroforestry value chain models: consortia concepts. Successful case studies	02
	Total	32

I. Course Title : Forest Stand Dynamics

II. Course Code : SAF 603

III. Credit Hours : 1+0

IV. Aim of the course

The purpose is to help silviculturists and forest managers to understand and anticipate how forests grow and respond to intentional manipulations and natural disturbances.

V. Theory

Unit I

Introduction-plant interactions and limitations of growth – mutualism and competition – the niche – limitations of growth – concept of growing space.

Unit II

Tree architecture and growth- general growth patterns – shoot development patterns, crown shapes, height growth, root growth, and tree development.

Unit III

Disturbances and stand development – impact of disturbances – major and minor-classification of disturbances – characteristics of disturbance agents. Stand structure and fire behaviour. Building resilience to disturbances.

Unit IV

Overview of stand development patterns – temporal and spatial patterns of tree invasion – stand initiation stage – stem exclusion stage – understorey reinitiation stage – old growth stage – multicohort stands – behaviour of component cohorts-development of multicohort stands – quantification of stand development – forest patterns over long times and large areas. Gap dynamics.

VI. Suggested Reading

Dagar JC, Tewari JC and Prasad V. 2018. *Agroforestry Anecdotal to Modern Science*. Springer.

Daniel TW, Helms JA and Baker FS. 1979. *Principles of Silviculture*, 2nd edition, McGraw-Hill, 2nd ed.

Kimmins JP. 1997. *Forest Ecology*, Macmillan Publishing Company, New York Upper Saddle River, Prentice Hall.

Koop H. 1989. *Forest Dynamics Silvi-star: A Comprehensive Monitoring System*. Springer-verlag. New York.

Oliver CD and Larson BC. 1996. *Forest Stand Dynamics*. John Wiley & Sons, Inc. New York New York: John Wiley & Sons, Inc.

Smith DM. 1986. *The Practice of Silviculture*, 8th ed, Wiley, New York.

Waring RH and Schlesinger WH. 1985. *Forest ecosystems: Concepts and management*, Academic. Press, San Diego.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction – plant interactions and limitations of growth – mutualism and competition- the niche – limitations of growth – concept of growing space	03

Sr. No	Topic	No. of Lecture(s)
2.	Tree architecture and growth- general growth patterns – shoot development patterns, crown shapes, height growth, root growth, and tree development	03
3.	Disturbances and stand development – impact of disturbances – major and minor- classification of disturbances – characteristics of disturbance agents	03
4.	Stand structure and fire behaviour. Building resilience to disturbances	03
5.	Overview of stand development patterns – temporal and spatial patterns of tree invasion – stand initiation stage – stem exclusion stage – understorey reinitiation stage – old growth stage	02
6.	Multicohort stands – behaviour of component cohorts- development of multicohort stands – quantification of stand development – forest patterns over long times and large areas. Gap dynamics	03
	Total	17

I. Course Title : Productivity and Evaluation of Agroforestry Systems

II. Course Code : SAF 604

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with concepts in agroforestry systems productivity, managing the factors of production and sustained yield levels.

V. Theory

Unit I

Concept of crop productivity. Productivity potential in relation to light, water and nutrients.

Unit II

System complementarity, supplementarity, competitiveness, sustainability and management techniques. Tree root architecture, re-allocation of resources within the plant system.

Unit III

Biological yield and harvest index. Growth and yield functions. Land equivalent ratio. Water use efficiency, photosynthetic efficiency, radiation balance, canopy transmissivity, canopy management, plant geometry and crop yield.

Unit IV

Allelopathic effects. Strategies to improve the efficiency and productivity of different land use systems.

Unit V

Role of various financing agencies in agroforestry and critical evaluation of different credit systems with emphasis on agroforestry. Methodologies for evaluating agroforestry hedonic pricing, PES, LER and LEV.

Unit VI

Financial, economic and social accounting of agroforestry projects. Advances in marketing management of agroforestry products. Evaluating combined productivity and profitability of different agroforestry systems *vis-a-vis* other competitive agro-based systems. Tree insurance schemes.

VI. Practical

- Techniques for leaf area index;
- Photosynthetically active radiation ;
- Soil moisture and leaf water potential;
- Canopy density measurements;
- Exercises on developing alternative optimal agroforestry plans under perfect and imperfect knowledge situations;
- Socio-economic and financial evaluation of agroforestry projects.

VII. Suggested Reading

Alavalapati JRR and D Evan Mercer. 2004. *Valuing Agroforestry Systems: Methods and applications*, Kluwer Academic Publishers.

Kant Shashi and Janaki Alavalapati. 2014. *Handbook of Forest Resource Economics,* Publisher: Routledge.

Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer.

Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*. ICRAF.

Sullivan, Gregory M, Susan M Hoke and Jefferson M Fox (editors). 1992. *Financial and Economic Analyses of Agroforestry Systems. Proceedings of a workshop held in Honolulu. Hawaii. USA. July* 1991. Paia, Ill: Nitrogen Fixing Tree Association.

Tejwani KG 1994. *Agroforestry in India* Oxford and IBH publishing Co. Pvt.Ltd.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Concept of crop productivity. Productivity potential in relation to light, water and nutrients	02
2.	System complementarily, supplementarity, competitiveness, sustainability and management techniques	03
3.	Tree root architecture, reallocation of resources within the plant system	02
4.	Biological yield and harvest index. Growth and yield functions. Land equivalent ratio	03
5.	Water use efficiency, photosynthetic efficiency, radiation balance, canopy transmissivity, canopy management, plant geometry and crop yield	03
6.	Allelopathic effects. Strategies to improve the efficiency and productivity of different land use systems	03
7.	Role of various financing agencies in agroforestry and critical evaluation of different credit systems with emphasis on agroforestry	03
8.	Methodologies for evaluating agroforestry hedonic pricing, PES, LER and LEV	03
9.	Financial, economic and social accounting of agroforestry projects	04
10.	Advances in marketing management of agroforestry products	02
11.	Evaluating combined productivity and profitability of different agroforestry systems *vis-a- vis* other competitive agrobased systems	03
12.	Tree insurance schemes	01
	Total	17

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Techniques for leaf area index, photosynthetically active radiation, soil moisture and leaf water potential and canopy density measurements.	6
	Exercises on developing alternative optimal agroforestry plans under perfect and imperfect knowledge situations.	6
2.	Socio-economic and financial evaluation of agroforestry projects.	4
	Total	16

I. Course Title : Forest Stand Management Techniques

II. Course Code : SAF 605

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding of students about advances in silviculture and silvicultural practice, effect of silvicultural practices on forest stand management and stand development, advances in coppice silviculture.

V. Theory

Unit I

Philosophy of silviculture – advance reproduction methods and their role in silviculture – Judging successful establishment; Analysis of active and passive site preparation – Silviculture with an ecosystem approach.

Unit II

Advances in silvicultural practices; tropical forest, sub-tropical forest and temperate forest.

Unit III

Analysis of different techniques of silviculture in forest stand management, Technique for early stand development; Analysis of thinning methods and its impact on wood yield and quality; Stand protection and health management. Silvicultural use of prescribed fire. Mechanization and role in silviculture.

Unit IV

Advance silviculture techniques for plantation forestry; Case studies of advance silviculture in India and abroad; mixed plantation forestry, Precision silviculture, silviculture of intensively managed plantations, silviculture for climate change mitigation. Sewage silviculture. Silviculture management for watershed and catchment areas. Silviculture for wildlife habitat improvement.

Unit V

Adjusting silviculture to meet industrial demands – silviculture in perspective – Problem solving procedure for silviculture – silviculture in retrospect.

VI. Practical

- Study of components of silvicultural system for sustained yield;
- Management strategies for even aged and uneven aged stands;
- Choice of site preparation methods, Plantation map, Quality planting stock, Planning for tree planting, Release cutting operation;

- Selection of thinning methods, Intensity of thinning;
- Analysis of site quality and biomass production for timber, pulp wood and fuel wood species;
- Problems in silviculture in tropical, subtropical plantation and their solutions.

VII. Suggested Reading

Brang P, Spathelf P, Larsen JB, Bauhus J, Bonèina A and Chauvin C. 2014. *Suitability of Close-To-Nature Silviculture for Adapting Temperate European Forests to Climate Change.* Forestry.

Colak AH, Rotherham ID and Calikoglu M. 2003. *Combining 'Naturalness Concepts' with Close-to-Nature Silviculture*. Forstwiss. Centralbl. 122, 421–431.

Cole DN and Yung L. (eds) 2010. *Beyond Naturalness: Rethinking Park and Wilderness Stewardship in an Era of Rapid Change*. Island Press.

Daniel TW, Helms JA and Baker FS. 1979. *Principles of Silviculture*, 2nd edition, McGraw-Hill, 2nd ed.

Fettig CJ, Reid ML, Bentz BJ, Sevanto S, Spittlehouse DL and Wang T. 2013. *Changing climates, changing forests: A western North American perspective*.

Franklin JF. 1989. *Towards a New Forestry*. Am. For.

Holm-Nielsen LB, Nielsen IC and Balsev H. (eds.) 1989. *Tropical Forests*, Academic Press, London.

Pukkala T and Gadow KV. 2012. *Continuous Cover Forestry*. 2nd Edition Springer.

Sairll PS, Evans J, Auclair D and Flack J. 1997. *Plantation Silviculture in Europe*. Oxford University Press.

Smith DM, Larson BC, Ketty MJ and Ashton PMS. 1997. *The Practices of Silviculture*: Applied Forest Ecology. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Philosophy of silviculture – Advance reproduction methods and their role in silviculture -judging successful establishment	01
2.	Analysis of active and passive site preparation -silviculture with an ecosystem approach	01
3.	Advances in silvicultural practices; tropical forest, sub-tropical forest and temperate forest	02
4.	Analysis of different techniques of silviculture in forest stand management, technique for early stand development	01
5.	Analysis of thinning methods and its impact on wood yield and quality	01
6.	Stand protection and health management. Silvicultural use of prescribed fire	01
7.	Mechanization and role in Silviculture	01
8.	Advance silviculture techniques for plantation forestry; Case studies of advance silviculture in India and abroad	02
9.	Mixed plantation forestry, Precision Silviculture, Silviculture of intensively managed plantations	01
10.	Silviculture for climate change mitigation. Sewage silviculture	01
11.	Silviculture management for watershed and catchment areas	01
12.	Silviculture for wildlife habitat improvement	01
13.	Adjusting silviculture to meet industrial demands-silviculture in perspective – Problem solving procedure for silviculture -silviculture in retrospect	02
	Total	16

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Study of components of silvicultural system for sustained yield	3
2.	Management strategies for even aged and uneven aged stands	3
3.	Selection of thinning methods, Intensity of thinning	3
4.	Analysis of site quality and biomass production for timber, pulp wood and fuel wood species	3
5.	Problems in silviculture in tropical, subtropical plantation and their solutions	4
	Total	16

I. Course Title : Agroforestry for Ecosystem Services and Environmental Benefits

II. Course Code : SAF 606

III. Credit Hours : 2+0

IV. Aim of the course

To develop understanding of students about ecosystem services and environmental benefits and quantification of ecosystem services and their valuation.

V. Theory

Unit I

Multifunctionality of agroforestry. Major ecosystem services and environmental benefits and international conventions and charters on climate change (UNFCCC, UNCCD, agroforestry and climate change negotiations: CoP) and biodiversity conservation (CBD) – an overview.

Unit II

Agroforestry for carbon conservation, sequestration, substitution – role and potentials of various agroforestry systems. Estimates of carbon sequestration potential – measurement – prospects and problems. Factors affecting above and belowground carbon sequestration potential.

Unit III

Agroforestry for soil enrichment – mechanisms – litter and fine root dynamics, rhizo-deposition and other rhizosphere effects, symbiotic and free-living N_2 fixation, mycorrhizal associations. Soil and water conservation benefits.

Unit IV

Agroforestry for biodiversity conservation. Synergy with climate change mitigation. Landscape connectivity for wildlife, supporting the pollinators of plant species. Agroforestry for improved air and water quality. Non-point source pollution in Indian agro-ecosystems. Riparian buffers for alleviating agricultural non-point source pollution.

Unit V

Private profitability vs. social profitability – exclusion or inclusion of social benefits and costs and non-market values, or externalities. Theory of externalities, effect of environmental costs and benefits on the profitability of agroforestry practices.

Valuing environmental services. Profitability of timber-based agroforestry systems. Costs and benefits in agroforestry- valuation of inputs and outputs- environmental outputs.

VI. Suggested Reading

Alavalapati JRR, Shrestha RK, Stainback GA and Matta JR. 2004. *Agroforestry development: An environmental Economic Perspective. Agroforestry Systems.* **61**: 299–310.

Huxley P. 1999. *Tropical Agroforestry*. Blackwell.

IPCC. 2007. "*Climate Change 2007*". *Mitigation of Climate Change*. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Jain SK and Singh P. 2000. *Economic Analysis of Industrial Agroforestry: Poplar (Populus deltoides) In Uttar Pradesh (India). Agroforestry Systems.* **49**: 255–273.

Jeffers JNR. 1978. *An Introduction to System Analysis with Ecological Application*. Edward Arnold.

Jose S. 2009. *Agroforestry for Ecosystem Services and Environmental Benefits: An Overview. Agroforestry Systems.* **76**: 1-10.

Lyngbaek AE, Muschler RG and Sinclair FL. 2001. *Productivity and Profitability of Multistrata Organic Versus Conventional Coffee Farms in Costa Rica. Agroforest. Syst.* **53**: 205–213.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer, Netherlands.

Schroth G and Sinclair F. 2003. *Tree Crops and Soil Fertility: Concepts and Research Methods*, CABI, Wallingford, UK.

Young A. 1997. *Agroforestry for Soil Management*. 2nd ed. CABI, Wallingofrd, UK.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Multifunctionality of agroforestry	01
2.	Major ecosystem services and environmental benefits and international conventions and charters on climate change (UNFCCC, UNCCD, agroforestry and climate change negotiations: CoP) and biodiversity conservation (CBD) – an overview	04
3.	Agroforestry for carbon conservation, sequestration, substitution – role and potentials of various agroforestry systems	03
4.	Estimates of carbon sequestration potential – measurement – prospects and problems. Factors affecting above and belowground carbon sequestration potential	04
5.	Agroforestry for soil enrichment – mechanisms – litter and fine root dynamics, rhizo-deposition and other rhizosphere effects, symbiotic and free-living N_2 fixation, mycorrhizal associations. Soil and water conservation benefits	03
6.	Agroforestry for biodiversity conservation. Synergy with climate change mitigation. Landscape connectivity for wildlife, supporting the pollinators of plant species	03
7.	Agroforestry for improved air and water quality. Non-point source pollution in Indian agro-ecosystems. Riparian buffers for alleviating agricultural non-point source pollution	03
8.	Private profitability vs. social profitability – exclusion or inclusion of social benefits and costs and nonmarket values, or externalities	03
9.	Theory of externalities, effect of environmental costs and benefits on the profitability of agroforestry practices	02
10.	Valuing environmental services. Profitability of timber-based agroforestry systems	03

Sr. No	Topic	No. of Lecture(s)
11.	Costs and benefits in agroforestry- valuation of inputs and outputs- environmental outputs	03
	Total	32

I. Course Title : Plantation Forest Productivity
II. Course Code : SAF 607
III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding of students about plantation forest productivity, dynamics of plantation growth, thinning and fertilization of plantation.

V. Theory

Unit I

Plantation forests – scope and perspectives, international and national scenario.

Unit II

Dynamics of plantation growth – site quality, stand density, dynamics of nutrient cycling, thinning, spacing and crown efficiency, nutrient pools and dynamics, biological factors in nutrient supply.

Unit III

Advances in site preparation techniques. Recent trends in fertilization and irrigation of plantations. Tending and cultural operations and plantation productivity – prospects of mechanization in tropical plantations. Reduced impact logging. Clonal forests, their management and productivity comparisons.

Unit IV

Productivity decline in plantation forests – second rotation decline – harvest related resource export – Modern silvicultural interventions.

Unit V

Project formulation, designing and appraisal of different kinds of plantations to meet specific objectives.

VI. Practical

- Plantation productivity analysis – growing stock and MAI assessment – stand density estimation;
- Fertilizers and fertilizer application in plantation;
- Response of plantation to irrigation;
- Productivity of clonal forestry;
- Modern tools in site preparation;
- Weed management methods;
- Management strategies for enhancing plantation productivity.

VII. Suggested Reading

Evans J and Turnbull JW. 2004. *Plantation Forestry in the Tropics: The Role, Silviculture and Use of Planted Forests for Industrial, Social, Environmental and Agroforestry Purposes.* OUP Oxford.

Evans J. 1982. *Plantation Forestry in the Tropics*. Clarendon Press.
Ford ED. 1984. *Nutrition of Plantation Forests*. Academic Press.
Krishnapillay B. 2000. *Silviculture and Management of teak plantations*. *Unasy*. 201. 51:14-21p.
Nambiar EKS, Cossalter C and Tiarks A. 1998. *Site Management and Productivity in Tropical Plantation Forests*. Workshop Proceedings, South Africa.
Sairll PS, Evans J, Auclair D and Flack J. 1997. *Plantation Silviculture in Europe*. Oxford University Press.
Smith DM. 1980. *The Practice of Silviculture*. 8th ed., John Wiley & Sons.
Suzuki K, Ishii K, Sakurai S and Sasaki S. 2006. *Plantation Forestry in the Tropics*. Springer Tokyo.
Zobel BJ, Wyk G and Stahlper P. 1987. *Growing Exotic Forests*. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Plantation forests – scope and perspectives, international and national scenario	02
2.	Dynamics of plantation growth – site quality, stand density, dynamics of nutrient cycling, thinning, spacing and crown efficiency, nutrient pools and dynamics, biological factors in nutrient supply	03
3.	Advances in site preparation techniques. Recent trends in fertilization and irrigation of plantations	02
4.	Tending and cultural operations and plantation productivity – prospects of mechanization in tropical plantations	02
5.	Reduced impact logging	01
6.	Clonal forests, their management and productivity comparisons	02
7.	Productivity decline in plantation forests – second rotation decline – harvest related resource export – Modern silvicultural interventions	02
8.	Project formulation, designing and appraisal of different kinds of plantations to meet specific objectives	03
	Total	17
	Practical	
1.	Plantation productivity analysis – growing stock and MAI assessment – stand density estimation	3
2.	Fertilizers and fertilizer application in plantation, response of plantation to irrigation	3
3.	Productivity of clonal forestry, modern tools in site preparation	4
4.	Weed management methods	2
5.	Management strategies for enhancing plantation productivity	4
	Total	16

I. Course Title : Restoration Forestry

II. Course Code : SAF 608

III. Credit Hours : 1+0

IV. Aim of the course

To develop understanding of students about advances in restoration forestry and forest landscape restoration.

V. Theory

Unit I

Introduction to restoration forestry, scope and opportunities for forest restoration, Natural regeneration, forest and land degradation in the Asia-Pacific region. Forest restoration techniques, tools for prioritization, decision-making and monitoring to enhance restoration success, The Bonn Challenge, The Bonn Challenge in Asia, Africa and Latin America.

Unit II

Forest landscape restoration, environment for natural regeneration in forest and landscape restoration, economic and social aspects for successful integration of natural regeneration in forest landscape restoration, adaptive management for forested landscapes in transformation, measures to improve resilient and genetically diverse forests. Mangrove restoration.

Unit III

Case studies on successful forest landscape restoration.

VI. Suggested Reading

Beatty CR, Cox NA and Kuzee ME. 2018. *Biodiversity Guidelines for Forest Landscape Restoration Opportunities Assessments*. First edition. Gland, Switzerland: IUCN.

Blakesley D and Buckley P. 2016. *Grassland Management and Restoration*. Conservation handbooks. Pelagic Publishing. Food and Agriculture Organization of the United Nations.

Chokkalingam U, Shono K, Sarigumba MP, Durst PB and Leslie R. (eds). 2018. *Advancing the Role of Natural Regeneration in Large-Scale Forest and Landscape Restoration in the Asia-Pacific Region*. FAO and APFNet. Bangkok.

FAO. 2010. *Forests Beneath the Grass*. Proceedings of the Regional Workshop on Advancing The Application of Assisted Natural Regeneration for Effective Low-Cost Forest *Restoration*. Bangkok, FAO.

FAO/ RECOFTC. 2016. *Forest Landscape Restoration in Asia-Pacific Forests*. by Appanah, S. (ed.). Bangkok, Thailand.198p

Prober SM, Byrne M, McLean EH, Steane DA, Potts BM, Vaillancourt RE and Stock WD. 2015. *Climate-Adjusted Provenancing: A Strategy for Climate-Resilient Ecological Restoration*. Frontiers in Ecology and Evolution, 23 June.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction to restoration forestry, scope and opportunities for forest restoration	01
2.	Natural regeneration, forest and land degradation in the Asia Pacific region	02
3.	Forest restoration techniques	02
4.	Tools for prioritization, decision-making and monitoring to enhance restoration success, The Bonn Challenge, The Bonn Challenge in Asia, Africa and Latin America.	03
5.	Forest landscape restoration, environment for natural regeneration in forest and landscape restoration, economic and social aspects for successful integration of natural regeneration in forest landscape restoration, adaptive management for forested landscapes in transformation	03

Sr. No	Topic	No. of Lecture(s)
6.	Measures to improve resilient and genetically diverse forests	02
	Mangrove restoration	01
7.	Case studies on successful forest landscape restoration	03
	Total	17

I. Course Title : Regeneration Silviculture

II. Course Code : SAF 609

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about advances in regeneration silviculture, forest continuum, advancement in artificial regeneration.

V. Theory

Unit I

Planning for regeneration, setting the objectives for regeneration, principles and methodologies of forest regeneration, ecological basis of natural regeneration techniques.

Unit II

Basic Concepts in forest regeneration, importance of different combinations of light, moisture, soil in determining success or failure of regeneration. Factors affecting natural and artificial regeneration- kinds, extent and quality of sites.

Unit III

Techniques of canopy manipulation and forest continuum in regular and irregular forests canopy, light pattern and regeneration establishment. Regeneration survey and methodology. Major silvicultural systems of tropical and temperate parts of the world. Continuous cover forestry. Advances in coppice silviculture. Silviculture in a changing world.

Unit IV

Advances in artificial regeneration techniques, advances in vegetative propagation techniques like mini and micro-cutting techniques, production technology for quality planting stock, carbon enrichment techniques for production of quality planting stock. Integrated nutrient management in nursery production. Plant quality assessment tools. Nursery production system of important timber and Non-Timber Forest Products, NTFP's yielding species in the region.

Unit V

Sustainable site establishment practices, Novel tree establishment techniques. Regeneration problems of important conifers and broad leaved species-case studies.

VI. Practical

- Factors affecting natural and artificial regeneration;
- Advances in vegetative propagation techniques like mini and micro-cutting techniques;
- Production technology for quality planting stock;

- Carbon enrichment techniques for production of quality planting stock;
- Integrated nutrient management in nursery production;
- Novel tree establishment techniques. Modern approaches in containerized seedling production.

VII. Suggested Reading

Colak AH, Rotherham ID and Calikoglu M. 2003. *Combining 'naturalness concepts' with close-to-nature silviculture*. Forstwiss. Centralbl. 122, 421–431.

Sairll PS, Evans J, Auclair D and Flack J. 1997. *Plantation Silviculture in Europe*. Oxford University Press.

Smith DM, Larson BC, Ketty MJ and Ashton PMS. 1997. *The Practices of Silviculture*: Applied Forest Ecology. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Planning for regeneration, setting the objectives for regeneration, principles and methodologies of forest regeneration, ecological basis of natural regeneration techniques	03
2.	Basic concepts in forest regeneration, importance of different combinations of light, moisture, soil in determining success or failure of regeneration	03
3.	Factors affecting natural and artificial regeneration- kinds, extent and quality of sites	02
4.	Techniques of canopy manipulation and forest continuum in regular and irregular forests canopy, light pattern and regeneration establishment	03
5.	Regeneration survey and methodology	02
6.	Major Silvicultural systems of tropical and temperate parts of the world. Continuous cover forestry	02
7.	Advances in coppice Silviculture. Silviculture in a changing world	02
8.	Advances in artificial regeneration techniques, advances in vegetative propagation techniques like mini and micro-cutting techniques, production technology for quality planting stock, carbon enrichment	02
9.	Techniques for production of quality planting stock. Integrated nutrient management in nursery production	02
10.	Plant quality assessment tools	04
11.	Nursery production system of important timber and Non-Timber Forest Products, NTFP's yielding species in the region	02
12.	Sustainable site establishment practices, Novel tree establishment techniques	02
13.	Regeneration problems of important conifers and broad leaved species-case studies	03
	Total	32
	Practical	
1.	Factors affecting natural and artificial regeneration,	2
2.	Advances in vegetative propagation techniques like mini and micro-cutting techniques,	3

Sr. No	Topic	No. of Practical(s)
3.	Production technology for quality planting stock,	3
4.	Carbon enrichment techniques for production of quality planting stock,	2
5.	Integrated nutrient management in nursery production.	2
6.	Novel tree establishment techniques.	2
7.	Modern approaches in containerized seedling production.	2
	Total	16

I. Course Title : Forest Soil Management

II. Course Code : SAF 610

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding of students about advances in forest soil management, forest soils and vegetation management.

V. Theory

Unit I

Forest soils and vegetation development. Physical properties of forest soils. Forest soil classification. Soils of the major forest biomes – soils under different forest types – tropical rainforest soils – moist deciduous forests – dry deciduous. Soils and plant roots.

Unit II

Soil chemistry and nutrient uptake. Soil organic matter – maintenance and buildup. Biology of forest soils – role of microorganisms in ameliorating soils; N and C cycles. Forest biogeochemistry. Micorrhizae. Role of forests in conserving soils.

Unit III

Nutrient transformation in soils. Nitrogen fixation in tropical forest plantations: N_2 fixation process, species, rates of N_2 fixation, factors influencing N_2 fixation; nutrient cycling – comparison of plantation productivity – case studies. Nutrition management: nutrient limitations, fertilization. Soil carbon sequestration – processes and mechanisms.

Unit IV

Soil management for reforestation of salt affected soils, acid soils, coastal soils. Effects of fire on soils and their properties.

Unit V

Management of long term soil productivity – soil compaction and erosion – harvest removal and nutrient budgeting – harvest effect on water quality – strategies for future management.

VI. Practical

- Nutrient budgeting for different plantation systems;
- Quantification of physical and chemical soil constraints in plantation and agroforestry systems;
- Evolving new strategies for soil and site development.

VII. Suggested Reading

Binkley D and R. Fisher. 2012. *Ecology and Management of Forest Soils* (4th Edition), John Wiley & Sons Singapore Pte. Ltd., Singapore.

Fisher RF, Binkley D and Pritchett WL. 2000. *Ecology and Management of Forest Soils*. 3rd Ed.John Wiley & Sons Inc., New York.

Havlin *et al.* 2014. *Soil Fertility and Fertilizers: An Introduction to Nutrient Management* (8th Edition), PHI Learning Pvt. Ltd., Delhi.

Khan TO. 2013 *Forest Soils: Properties and Management*, Springer International Publishing, Switzerland.

Pritchett and Fisher RF 1987. *Properties and Management of Forest Soils*. John Wiley, New York.

Reddy MV. 2001. *Management of Tropical Plantation Forests and Their Soil Litter System-Litter, Biota and Soil Nutrient Dynamics*. Science Publishers, U.S.

Sadanandan Nambiar EK and Grown AG. (Eds.). 1997. *Management of Soil, Nutrients and Water in Tropical Plantation Forests*. ACIAR, CSIR and CIFOR, Australia.

Schulte A and Ruhiyat D. 1998. *Soils of Tropical Forest Ecosystems*: *Characteristics, Ecology, and Management*. Springer Verlag,Berlin, New York.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Forest soils and vegetation development	01
2.	Physical properties of forest soils, Forest soil classification	01
3.	Soils of the major forest biomes – soils under different forest types – tropical rainforest soils – moist deciduous forests – dry deciduous	01
4.	Soils and plant roots, Soil chemistry and nutrient uptake	01
5.	Soil organic matter – maintenance and buildup	01
6.	Biology of forest soils – role of microorganisms in ameliorating soils; N and C cycles	01
7.	Forest biogeochemistry. Micorrhizae. Role of forests in conserving soils	01
8.	Nutrient transformation in soils	01
9.	Nitrogen fixation in tropical forest plantations: N_2 fixation process, species, rates of N fixation, factors influencing N_2 fixation	01
10.	Nutrient cycling – comparison of plantation productivity – case studies	01
11.	Nutrition management: nutrient limitations, fertilization	01
12.	Soil carbon sequestration – processes and mechanisms	01
13.	Soil management for reforestation of salt affected soils, acid soils, coastal soils	01
14.	Effects of fire on soilsand their properties	01
15.	Management of long term soil productivity – soil compaction and erosion – harvest removal and nutrient budgeting	01
16.	Harvest effect on water quality – strategies for future management	01
	Total	16
	Practical	
1.	Nutrient budgeting for different plantation systems,	5
2.	Quantification of physical and chemical soil constraints in plantation and agroforestry systems,	6
3.	Evolving new strategies for soil and site development	5
	Total	16

I. Course Title : Agroforestry For Sustainable Agriculture

II. Course Code : SAF 611

III. Credit Hours : 1+0

Aim of the course

To develop understanding of students about the role of agroforestry in sustainable agriculture, current agricultural scenario, role of trees in enhancing productivity of agricultural land on sustainable basis.

IV. Theory

Unit I

Current Agricultural scenario in India. Sustainable agriculture: issues and challenges. Land use changes- agroforestry: an opportunity for sustainability and rainfed agriculture.

Unit II

Agroforestry options for sustainable agriculture: integration of perennial components in agriculture. Role of trees in enhancing the productivity of traditional agriculture. Strategies on integration of trees suitable for different cropping systems for important agro-ecological regions. Tree management for productivity optimization.

Unit III

Agroforestry for different land holdings. Integrated farming systems. Agroforestry strategies for short term and long term returns.

Unit IV

Processing, value addition and marketing of agroforestry products.

V. Suggested Reading

Chin K Ong, Colin Black and Julia Wilson. 2015. *Tree-Crop Interactions*, 2nd Edition: Agroforestry in a Changing Climate. CAB International ICRAF.

Nair PKR, Rai MR and Buck LE. 2004. *New Vistas in Agroforestry*. Kluwer.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer, Netherlands.

Ong CK and Huxley PK. 1996. *Tree Crop Interactions – A Physiological Approach*.

Schroth G and Sinclair F. 2003. *Tree Crops and Soil Fertility: Concepts and Research Methods*. CABI, Wallingford, UK.

Snelder DJ and Lasco RD. 2008. *Smallholder Tree Growing for Rural Development and Environmental Services*. Springer Science, Amsterdam.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Current Agricultural scenario in India. Sustainable agriculture: Issues and challenges and land use changes	02
2.	Agroforestry: An opportunity for sustainability and rainfed agriculture	02
3.	Agroforestry options for sustainable agriculture: Integration perennial components in agriculture	02
4.	Role of trees in enhancing the productivity of traditional agriculture	01
5.	Strategies on integration of trees suitable for different cropping systems for important agro-ecological regions. Tree management for productivity optimization	03

Sr. No	Topic	No. of Practical(s)
6.	Agroforestry for different land holdings. Integrated farming systems	02
7.	Agroforestry strategies for short term and long term returns	02
8.	Processing, value addition and marketing of agroforestry products	03
	Total	17

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Forestry
– Forest Biology and Tree Improvement

Course Title with Credit Load M.Sc. (Forestry) in Forest Biology and Tree Improvement

Course Code		Course Title	Credit Hours
		Major Courses	
FBT 501 *	I	Applied Forest Tree Improvement	2+1
FBT 502	II	Forest Ecology and Biodiversity Management	2+1
FBT 503*	I	Breeding Methods in Forest Trees	2+1
FBT 504	II	Reproductive Biology of Forest Trees	2+1
FBT 505	I	Tree Seed Orchards	2+1
FBT 506*	II	Quantitative Genetics in Forest Tree Breeding	2+1
FBT 507	I	Forest Genetic Diversity and Conservation	3+0
FBT 508*	II	Biotechnology in Forestry	2+1
FBT 509	I	Clonal Forestry	2+0
FBT 510	II	Forest Ecophysiology	2+1
FBT 511	I	Physiology of Woody Plants	2+1
FBT 512	II	Breeding for Insect Pest and Disease Resistance in Trees	2+1
FBT 513	I	Tree Seed Technology	2+1
		Minor Courses	
		Courses from Silviculture and Agroforestry or Forest Products and Utilization	08
		Supporting Courses	
FOR 511*	I	General Statistical Methods and Computer Applications	2+1
		Any other course relavent to MSc research problem	03
		Common Courses	
		Library and Information Services	1+0
		Technical Writing and Communications Skills	1+0
		Intellectual Property and its management in Agriculture	1+0
		Basic Concepts in Laboratory Techniques	1+0
		Agricultural Research, Research Ethics and Rural Development Programmes	1+0
FBT 591*	I/ II	Master's Seminar	1+0
		ii) Thesis Research	
FBT 599		Master's Research	0+30

*Compulsory Core Courses

Course Contents
M.Sc. (Forestry) in Forest Biology and Tree Improvement

I. Course Title : Applied Forest Tree Improvement

II. Course Code : FBT 501

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students about general principles of tree breeding with examples of important trees.

V. Theory

Unit I

General concept of forest tree breeding, tree improvement and forest genetics.

Unit II

Reproduction in forest trees, dimorphism, pollination mechanism. Pollen dispersal, pollinators. Attractants for pollinators.

Unit III

Variation in trees, importance and its causes. Natural variations as a basis for tree improvement. Geographic variations – Ecotypes, clines, races and land races.

Unit IV

Selective breeding methods- mass, family, within family, family plus within family. Plus tree selection for wood quality, disease resistance and agroforestry objectives. Selection strategies and choice of breeding methods and progress in selective breeding in forest trees.

Unit V

Seed orchards – type, functions and importance,Genetic testing- mating designs and field designs. Progeny and clone testing estimating genetic parameters and genetic gain, clonal and breeding values. Average performance of half sibs and full-sibs. GxE interaction in trees.

Unit VI

Heterosis breeding: inbreeding and hybrid vigour. Manifestation and fixation of heterosis. Species and racial hybridization. Indian examples – teak, shisham, eucalypts, acacias, poplar, etc.

Unit VII

Polyploidy, aneuploidy and haploidy in soft and hard wood species. Induction of polyploidy.

Unit VIII

Elements of biotechnology in tree improvement.

VI. Practical

- Floral biology, modes of reproduction and modes of pollination in forest trees;

- Estimating pollen viability. Controlled pollination and pollen handling;
- Manipulation of flowering through hormones;
- Identification of ecotypes, races and land-races in natural forest;
- Visit to species, provenance and progeny trials;
- Selection of superior phenotypes;
- Marking of candidate trees, plus trees and elite trees;
- Visit to seed orchards;
- Comparison of parents and their putative hybrids;
- Induction of polyploidy through colchicine treatment;
- *In-vitro* propagation, study of molecular markers.

VII. Suggested Reading

Dutta M and Saini GC. 2009. *Advances in Forestry Research in India*, Vol. XXX. Forest Tree Improvement and Seed Technology. International Book Distributors.

Finkeldey R and Hattemer HH. 2006. *Tropical Forest Genetics*. Springer.

Mandal AK and Gibson GL. (Eds). 1997. *Forest Genetics and Tree Breeding*. CBS.

Sedgley M and Griffin AR. 1989. *Sexual Reproduction of Tree Crops*. Academic Press.

Surendran C, Sehgal RN and Paramathma M. 2003. *Text Book of Forest Tree Breeding*. ICAR.

White TL, Adams WT and Neale DB. 2007. *Forest Genetics*. CABI, UK.

Wright JW. 1976. *Introduction to Forest Genetics*. Academic Press.

Zobel BJ and Talbert J. 1984. *Applied Forest Tree Improvement*. John Wiley and Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	General concept of forest tree breeding, tree improvement and forest genetics	1
2.	Reproduction in forest trees – dimorphism, pollination mechanism, pollen dispersal, pollinators, attractants for pollinator	5
3.	Variation in trees importance and its causes. Natural variation as a basis for tree improvement. Geographic variations – ecotypes, clines, races and land races	2
4.	Plus tree selection for wood quality, disease resistance and agroforestry objectives	2
5.	Selective breeding methods- mass, family, within family, family plus within family	2
6.	Selection strategies and choice of breeding methods and progress in selective breeding in forest trees	2
7.	Progeny and clone testing. Estimating genetic parameters and genetic gain Clonal and breeding values	2
8.	Seed orchards – type, functions and importance, Genetic testing-mating designs and field designs	2
9.	Average performance of half sibs and full sibs, GxE interaction in trees	2
10.	Heterosis breeding: inbreeding and hybrid vigour Manifestation and fixation of heterosis. Species and racial hybridization. Indian examples – teak, sal, shisham, eucalypts, acacias, pines and poplars	3
11.	Polyploidy, aneuploidy and haploidy in soft and hard wood species. Induction of polyploidy	2
12.	Mutation breeding	2
13.	Elements of Biotechnology in tree improvement	5
	Total	32

Sr. No.	Topic	No. of Practical(s)
	Practical	
1.	Floral biology, modes of reproduction and modes of pollination in forest trees	2
2.	Estimating pollen viability. Controlled pollination and pollen handling	2
3.	Manipulation of flowering through hormones	2
4.	Identification of ecotypes, races, and land-races in natural forest	1
5.	Visit to species, provenance and progeny trials	1
6.	Selection of superior phenotypes. Marking of candidate trees, plus trees and elite trees	1
7.	Visit to seed orchards	1
8.	Comparison of parents and their putative hybrids	1
9.	Induction of polyploidy through colchicine treatment	1
10.	*In-vitro* propagation	2
11.	Study of molecular markers	2
	Total	16

I. Course Title : Forest Ecology And Biodiversity Management

II. Course Code : FBT502

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding among students about ecological aspects of forest, conservation of forest resources and biodiversity, consequences of depleting biodiversity and concept of sustainability.

V. Theory

Unit I

Hierarchy issues in ecology and ecosystem.Advanced topics in forest ecology including forest population, forest community dynamics, forest community structure and analysis, forest productivity, ecology of forest landscapes spatial heterogeneity and ecological succession.

Unit II

Conservation of natural resources (hotspot areas, wildlife sanctuaries, national parks, biosphere reserve). Climate change, Global warming and forests. Green house effect and its consequences. Ozone depletion. Conservation laws and acts. Forest genetics resources of India: timber and non timber species. Survey exploration and sampling strategies Phytogeography and vegetation types of India.

Unit III

Documentation and evaluation of forest genetical resources (FGR), *in situ* and *ex situ* conservation of gene resources. Phytodiversity and its significance to sustainable use. Handling and storage of FGR. Intellectual property rights. Quarantine laws and FGR exchange.

VI. Practical

- Study of forest community structure and its successional status;
- Estimation of productivity of forest ecosystem;

- Study tours to different regions of the state to study forest vegetation;
- Collection and preservation of specimen, Methods of vegetation analysis;
- Measurement of biomass and productivity;
- Quantification of litter production and decomposition;
- Visit to national parks, wildlife sanctuaries. Botanical gardens and arboreta.

VII. Suggested Reading

Avery TE and Burkharts H. 2001. *Forest Measurements*. McGraw-Hill Education.

Barnes BV, Zak DR, Denton SR and Spurrs SH. 1998. *Forest Ecology*. Wiley.

Jha BC, Pandey BN, Jaiswal K, Katiha PK, Pandey PN and Sharma AP. 2012. *Biodiversity: Issues Threats and Conservation*. Narendra Publishing House, Delhi.

Kumar Biju. 2013. *Biodiversity and Taxonomy*. Narendra Publishing House, Delhi.

Larocque GR. 2016. *Ecological Forest Management Handbook (Applied Ecology and Environmental Management*). Taylor & Francis.

Mahato B, Pandy BN, Singh LB, Panday PN and Singh RK. 2010. *Text Book of Environmental Pollution*. Narendra Publishing House, Delhi.

Mikusiñski G, Roberge JM and Fuller R. 2018. *Ecology and Conservation of Forest Birds* (*Ecology, Biodiversity and Conservation*). Cambridge University Press.

Pandey PN. 2009. *Biodiversity and Environment Ecology*. Narendra Publishing House, Delhi.

Perry DA, Oren R and Hart SC. 2008. *Forest Ecosystems*. 2nd ed. Baltimore: Johns Hopkins University Press.

Young RA and Giese RL. 2003. *Introduction to Forest Ecosystem Science and Management*. Wiley.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Hierarchy issues in ecology and ecosystem	3
2.	Advanced topics in forest ecology including forest population, forest community dynamics, forest community structure and analysis	3
3.	Forest productivity, ecology of forest landscapes spatial heterogeneity and ecological succession	3
4.	Conservation of natural resources (hotspot areas, wildlife sanctuaries, national parks, biosphere reserve)	3
5.	Climate change, global warming and forests. Green house effect and its consequences	2
6.	Ozone depletion. Conservation laws and acts	2
7.	Forest genetics resources of India: timber and non timber species	3
8.	Survey exploration and sampling strategies Phytogeography and vegetation types of India	2
9.	Documentation and evaluation of forests genetical resources (FGR)	2
10.	*In situ* and *ex situ* conservation of gene resources	3
11.	Phytodiversity and its significance to sustainable use. Handling and storage of FGR	3
12.	Intellectual property rights	2
13.	Quarantine laws and FGR exchange	2
	Total	33
	Practical	
1.	Study of forest community structure and its successional status	2

Sr. No.	Topic	No. of Practical(s)
2.	Estimation of productivity of forest ecosystem	2
3.	Study tours to different regions of the state to study forest vegetation	2
4.	Collection and preservation of specimen	2
5.	Methods of vegetation analysis	2
6.	Measurement of biomass and productivity	2
7.	Quantification of litter production and decomposition	2
8.	Visit to national parks, wildlife sanctuaries, botanical gardens and arboreta	2
	Total	16

I. Course Title : Breeding Methods in Forest Trees

II. Course Code : FBT 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students about the concepts of sub-selection, population structure for breeding and production, genetic testing and making designs.

V. Theory

Unit I

Genetic constitution of tree populations, half-sib, full-sib family in trees. Hardy-Weinberg equilibrium, changes in gene frequency through selection, migration, mutation and population sizes.

Unit II

Long-term and short-term breeding populations. Selective breeding methods- mass, family, within family, family plus within family. Grading system of plus trees in natural stands and plantations selection index, regression systems, mother tree selection and subjective evaluation. Selection for different traits.

Unit III

Genetic testing programmes – mating designs, complete designs – nested designs, factorial, single pair mating, full diallel, half diallel and partial diallel, incomplete pedigree designs – open pollinated mating and polycross mating. Improvement through progeny testing.

Unit IV

Experimental designs in genetic testing. Breeding methods for wood quality, diseases and pest resistance, drought and salt resistance. Testing procedures for genetic advancement. Marker assisted selection.

Unit V

Tree improvement case histories.

VI. Practical

- Half-sib, full-sib family in trees;
- Grading system of plus trees in natural stands;
- Mating designs, complete pedigree designs – nested designs, factorial, single pair

mating, full diallel, half diallel and partial diallel, incomplete pedigree designs – open pollinated mating and polycross mating;
- Selection for biotic and abiotic stresses.

VII. Suggested Reading

Acquaah G. 2012. *Principal of Plant Genetics and Breeding*. John Wiley & Sons, Ltd, UK.

Falconer DS and Mackay TFC. 1995. *Introduction to Quantitative Genetics*. 4th edition. Longman, Essex

Mandal AK and Gibson GL. 2002. *Forest Genetics and Tree breeding*. CBS Publishers

Namkoong G, Kang HC and Brouard JS 1988. *Tree breeding: Principles and Strategies*. Springer Verlag, New York.

Surendran C, Sehgal RN and Parmathama M. (Eds.). 2003. *A Text Book of Forest Tree Breeding*. ICAR.

White TL and Hodge GR 1989. *Predicting Breeding Values with Applications in Forest Tree Improvement*. Kluwer Academic Publishers, Boston.

White TL, Adams WT and Neale DB. 2007. *Forest Genetics*. CABI

Wright JW. 1962. *Genetics of Forest Tree Improvement*. Academic Press.

Wright JW. 1976. *Introduction to Forest Genetics*. Academic Press.

Zobel BJ and Talbert J. 1984. *Applied Forest Tree Improvement*. John Wiley and Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction	1
2.	Hardy-Weinberg equilibrium, changes in gene frequency through selection, migration, mutation and population sizes	5
3.	Grading system of plus trees in natural stands and plantations regression systems, mother tree selection, subjective evaluation	2
4.	Selective breeding methods- mass, family, within family, family plus within family	2
5.	Long-term and short-term breeding populations	4
6.	Genetic testing programmes – mating designs, Incomplete pedigree designs – open pollinated mating and polycross mating	2
7.	Complete designs (nested designs, factorial, single pair mating, full diallel, half diallel and partial diallel)	2
8.	Experimental designs in genetic testing	2
9.	Marker assisted selection	2
10	Breeding methods for disease resistance	2
11.	Breeding methods for water stress	2
12.	Breeding methods for pest resistance	2
13.	Tree improvement case histories. Breeding strategy for pines and eucalyptus	4
	Total	32
	Practical	
1.	Grading system of plus trees in natural stands, plantation	1
2.	Mating designs	1
3.	Complete designs – nested designs	2
4.	Factorial	4
5.	Single pair mating	2
6.	Full diallel, Half diallel and Partial diallel	4

Sr. No.	Topic	No. of Lecture(s)
7.	Incomplete pedigree designs – open pollinated mating and polycross mating	2
	Total	**16**

I. Course Title : Reproductive Biology of Forest Trees

II. Course Code : FBT 504

III. Credit Hours : 2+1

IV. Aim of the course

To impart the knowledge of reproduction in forest tree species to the students and to make them understand the mechanism of breeding and sex expression.

V. Theory

Unit I

Importance and application of reproductive biology in tree breeding. Crop characteristics-growth and development (both vegetative and reproductive).

Unit II

Floral diversity and pollination. Flower types pollination syndromes and their evolution. Plant – pollinator systems. Diversity of pollination syndromes in selected plant families. Modes of reproduction-sexual, asexual and vegetative and their breeding systems and sex expression, monoecy, dioecy and its evolution.

Unit III

Environmental effects on sex expression. Floral biology. Modes of pollination self and out-crossing. Floral attractants and rewards biology of floral and extrafloral nectaries examples of plant insect interactions involving pollination. Floral characteristics of the main pollination syndromes.

Unit IV

Environmental effects on sex expression. Floral biology initiation and development. Modes of pollination self and out-crossing.

Unit V

Fertilization in hardwood and softwood species. Seed dispersal and gene flow.

VI. Practical

- Sex expression in forest trees;
- Out crossing mechanisms in forest trees;
- Measurement of pollen flow in wind-pollinated and insect-pollinated species;
- Pollen viability and fertility;
- Seed dispersal mechanism.

VII. Suggested Reading

Almeida OJG, Cota K Sánchez JH and Paoli AAS. 2013. *The systematic significance of floral morphology, nectaries and sugar nectar concentration in epiphytic cacti of tribes Hylocereeae and Rhipsalideae* (Cactaceae). Persp. Plant Ecol. Evol. Syst. 15: 255-268.

Barrett SCH. 2006. *Ecology and Evolution of Flowers* [electronic resource]. (Eds.) L.D. Harder SCH. Barrett. Oxford Univ. Press, New York, U.S.A.
Bawa KS and Hadley M. 1990. *Reproductive Ecology of Tropical Forest Plants*. UNESCO Man and Biosphere Series.
Briggs and Walters SM. 1984. *Plant Variation and Evolution*.
Cláudia Inês da Silva and Helena Maura Torezan Silingardi. 2006. *Reproductive Biology of Tropical Plants* – International Commission On Tropical Biology and Natural Resources. Encyclopedia of Life Support Systems (EOLSS)
FAO. 1985. *Forest Tree Improvement,* FAO Publication.
Khosla PK. 1981. *Advances in Forest Genetics*. Ambika Publ., New Delhi.
Mandal AK and Gibson GL. (Eds.). 1997. *Forest Genetics and Tree Breeding*. CBS.
Sedgley and Griffin. 1989. *Sexual Reproduction of Tree Crops*.
Spencer C H, Barrett, Robert I, Colautti and Christopher G Eckert. 2007. *Plant Reproductive Systems and Evolution during Biological Invasion*. Wiley Online Library. (https://doi.org/10.1111/ j.1365-294X.2007.03503.x).

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Importance and application of reproductive biology in tree breeding	1
2.	Crop characteristics-growth and development (both vegetative and reproduction)	4
3.	Floral diversity and pollination. Flower types: Pollination syndromes and their evolution; Plant – pollinator systems, Diversity of pollination syndromes in selected plant families	4
4.	Modes of reproduction: sexual, asexual and vegetative and their breeding systems and sex expression, monoecy, dioecy and its evolution	5
5.	Environmental effects on sex expression	3
6.	Floral biology. Initiation and development. Modes of pollination; self and out-crossing	3
7.	Floral attractants and rewards; Biology of floral and extra floral nectarines; Examples of plant insect interactions involving pollination. Floral characteristics of the main pollination syndromes	5
8.	Fertilization in hardwood and softwood species	3
9.	Seed dispersal and gene flow	4
	Total	32
	Practical	
1.	Sex expression in forest trees	2
2.	Out crossing mechanisms in forest trees	3
3.	Measurement of pollen flow in wind-pollinated and insect-pollinated species	3
4.	Pollen viability and fertility	2
5.	Seed dispersal mechanism	3
6.	Study of reproductive biology of Eucalyptus, Pine, Shishum, etc.	3
	Total	16

I. Course Title : Tree Seed Orchards

II. Course Code : FBT 505

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding among students about tree seed orchards.

V. Theory

Unit I

Importance of genetically improved seed in plantation forestry. Status of seed production among major plantation species. Short term supply of superior seed.

Unit II

Selection and delineation of seed stands, seed production areas, seed zones, seed ecological zones.

Unit III

Seed orchard: need, evolving seed orchards, containerized seed, hybrid and research seed orchards; first, second and advanced generation seed orchards. Seed orchard genetics: random mating, gamete exchange and parental balance. Estimation of genetic parameters from seed orchard data. Ortet age and its effect on seed production.

Unit IV

Importance of progeny testing. Establishment of seed orchards, selection and preparation of orchard site, isolation, orchard size, and designs. Seed orchard management: rouging, silvicultural practices to increase seed yield.

Unit V

Pest and disease management. Seed collection and record keeping, seed orchard registration and documentation. Importance of seed orchards in gene conservation.

VI. Practical

- Visits and study of seed orchard designs;
- Estimation of overlap in flowering among genotypes;
- Study of inter and intra-clonal variation in floral, seed characters;
- Effect of girdling on flowering;
- Plant growth regulator application for flower induction;
- Pollen viability/ fertility;
- Assessment of pollen dispersa;.
- Supplemental mass-pollination;
- Effects of foliar application of fertilizers on seed set;
- Estimation of genetic parameters for a few traits;
- Estimation of parental balance.

VII. Suggested Reading

Faulkner R. 1975. *Seed Orchard* Forestry. Commission Bull. No. 34.
Fins L, Friedman ST and Brotschol JV. 1992. *Handbook of Quantitative Forest Genetics*. Kluwer.
Khosla PK. 1981. *Advances in Forest Genetics*. Ambika Publ., New Delhi.
Mandal AK and Gibson GL. (Eds.). 1997. *Forest Genetics and Tree Breeding*. CBS.
Nanson A. 2004. *Genetics of Forest Tree Breeding*. Agronomic Press

Surendran C, Sehgal RN and Parmathama M. (Eds.). 2003. *A Text Book of Forest Tree Breeding*. ICAR.
Wright JW. 1976. *Introduction to Forest Genetics*. Academic Press.
Zobel BJ and Talbert J. 1984. *Applied Forest Tree Improvement*. John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Importance of genetically improved seed in plantation forestry	1
2.	Status of seed production among major plantation species	2
3.	Short term supply of superior seed	1
4.	Selection and delineation of seed stands, seed production areas, seed zones, seed ecological zones	4
5.	Seed orchard: need, evolving seed orchards, containerized seed, hybrid and research seed orchards; first, second and advanced generation seed orchard. Seed orchard genetics: random mating, gamete exchange and parental balance	6
6.	Estimation of genetic parameters from seed orchard data. Ortet age and its effect on seed production	3
7.	Importance of progeny testing	2
8.	Establishment of seed orchards, selection and preparation of orchard site, isolation, orchard size, and designs	4
9.	Seed orchard management: rouging, silvicultural practices to increase seed yield. Supplemented mass pollination. Pest and disease management. Seed collection and record keeping, seed orchard registration and documentation	5
10.	Importance of seed orchards in gene conservation	2
12.	Status of seed production among major plantation species	2
	Total	32
	Practical	
1.	Visits and study of seed orchard designs.	2
2.	Estimation of overlap in flowering among genotypes.	2
3.	Study of inter and intra-clonal variation in floral and seed characters.	2
4.	Effect of girdling on flowering.	2
5.	Plant growth regulator application for flower induction.	2
6.	Pollen viability/ fertility.	1
7.	Assessment of pollen dispersal.	2
8.	Supplemental mass-pollination.	2
9.	Effects of foliar application of fertilizers on seed set.	1
	Total	16

I. Course Title : Quantitative Genetics in Forest Tree Breeding

II. Course Code : FBT 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowlewge in the field of biometry as applied to breeding, population, provinces and making experiment in forest genetics and tree breeding.

V. Theory

Unit I

Historical aspects of quantitative genetics. Inheritance of continuously varying characters, Genetic variance and its partitioning, models of gene action. Multiple factor hypothesis (Nilsson-Ehle (1908) and East (1915) experiments.

Unit II

Mating systems, population structure in random mating. Hardy Weinberg law, Effect of selection, mutation, migration, genetic drift; on genes and genotypic frequency.

Unit III

Inbreeding, effects of inbreeding in various populations. Heterosis, causes of heterosis and its utility in various plants.

Unit IV

Significance and estimation of genetic variance components. Heritability, its estimation by various methods and significance.

Unit V

Natural selection, fundamental theorem of natural selection (Fisher 1930). Selection responses. Correlation and its utility. Partitioning of correlation into direct and indirect effects.

Unit VI

Mating design, combining ability, general and specific combining ability and methods of its estimation.

Unit VII

Genotypic x environment interaction, its significance. Various procedures for the estimation of genotypic x environment interaction.

VI. Practical

- Exercise on polygenic inheritance;
- Proof that quantitative characters are inherited in Mendelian fashion;
- Estimation of genotypic and phenotypic variance in an experiment, estimation of additive and dominance components of variance through various procedures;
- Mating designs and estimation of components of genetic variance;
- Proof of population genetics law;
- Exercise on calculation of gene and genotypic frequency;
- Estimation of heterosis, estimation of heritability (broad sense and narrow sense) by various methods;
- Genotypic and phenotypic correlation coefficients, partitioning of correlation into direct and indirect effects;
- Estimation of general combining ability and specific combining ability;
- Estimation of genotypic x environment interaction.

VII. Suggested Reading

Acquaah G. 2012. *Principal of Plant Genetics and Breeding*. John Wiley & Sons, Ltd, UK. Kute N and Shinde G. 2016. *Principles of Biometrical Genetics*. Daya publishing.

Fins Lauren, Friedman ST and Brotschol JV. (Eds.). 1992. *Handbook of Quantitative Forest Genetics*. Springer, Netherlands.
Gene Namkoong. 1979. *Introduction to Quantitative Genetics In Forestry. Technical Bulletin No. 1588*. Forest Service United States Department of Agriculture Washington,D. C.
Singh RK and Chaudhary BD. 1985. *Biometrical Methods in Quantitative genetical Analysis*. Kalyani Publishers, New Delhi.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Historical aspects of quantitative genetics	1
2.	Genetic variance and its partitioning, models of gene action	3
3.	Inheritance of continuously varying characters	2
4.	Multiple factor hypothesis (Nilsson-Ehle (1908) and East (1915) experiments	2
5.	Mating systems, population structure in random mating	3
6.	Hardy Weinberg law, effect of selection, mutation, migration, genetic drift: on genes and genotypic frequency	3
7.	Inbreeding, effects of inbreeding in various populations	2
8.	Heterosis, causes of heterosis and its utility in various plants	2
9.	Significance and estimation of genetic variance components. Heritability, its estimation by various methods and significance	2
10.	Natural selection, fundamental theorem of natural selection (Fisher 1930)	2
11	Selection responses. Correlation and its utility. Partitioning of correlation into direct and indirect effects	2
12.	Mating designs	3
13.	Combining ability, general and specific combining ability and methods of its estimation	2
14.	Genotypic × environment interaction, its significance. Various procedures for the estimation of genotypic x environment interaction	3
	Total	32
	Practical	
1.	Polygenic inheritance	2
2.	Proof that quantitative characters are inherited in Mendelian fashion	1
3.	Estimation of genotypic and phenotypic variance in an experiment through various procedures	2
4.	Mating designs and estimation of additive and dominance components of variance components of genetic variance	3
5.	Proof of population genetics law	1
6.	Calculation of gene and genotypic frequency	1
7	Estimation of heterosis, estimation of heritability (broad sense and narrow sense) by various methods	2
8.	Genotypic and phenotypic correlation coefficients, partitioning of correlation into direct and indirect effects	1
9.	Estimation of general combining ability and specific combining ability	1
10.	Estimation of genotypic x environment interaction	2
	Total	16

I. Course Title : Forest Genetic Diversity and Conservation

II. Course Code : FBT 507

III. Credit Hours : 3+0

IV. Aim of the course

To provide the knowledge about the genetic diversity in forest tree species, their distribution, assess and analysis and methodologies of *in-situ* and *ex-situ* conservation.

V. Theory

Unit I

Phytodiversity-concept, levels ecosystem. Genetic diversity and differentiation-definition, characteristics and importance for tree breeding. Genetic erosion. Techniques to assess genetic diversity. Analysis of karyotypic variation.

Unit II

Molecular approaches for assessing genetic diversity. Inventory and monitoring biodiversity: sampling strategies for genetic diversity assessments sufficiency of sampling procedures, neutral allele model and optimal allocation of sampling efforts.

Unit III

Methods of sampling of genetic diversity. Factors influencing levels of genetic diversity in woody plant species. Conservation of genetic diversity Conservation biology and invasive species.

Unit IV

Laws and policies. Methods for maintenance of conservation: gene banks, arboreta, botanical gardens, breeding populations as repositories of gene conservation. Rare, threatened biodiversity, endangered and endemise plants.

Unit V

Techniques for survey and assessment of endangered plants. Rarity patterns and endemism. Concept of island biogeography. Managing corridors and natural habitat fragments.

Unit VI

Monitoring and recovery plans for endangered plants. Plant community reserves. Managing wild flora tourism impacts and eco tourism and urban forestry of rare/exotic plants. Implications of rarity.

VI. Suggested Reading

Engles JMM, Rao VR Brown AHD and Jackson MT. 2002. *Managing Plant Genetic Diversity*. CABI and IPGRI.

FAO. 1985. *Forest Tree Improvement*, FAO Publication.

Fins L, Friedman ST and Brotschol JV. 1992. *Handbook of Quantitative Forest Genetics*. Kluwer.

IPGRI. 2004. *Forest Genetic Resources Conservation and Management*. Vol. 1, 2 and 3.

Khosla PK. 1981. *Advances in Forest Genetics*. Ambika Publ., New Delhi.

Mandal AK and Gibson GL. (Eds.). 1997. *Forest Genetics and Tree Breeding*. CBS.

Surendran C, Sehgal RN and Parmathama M. (Eds.). 2003. *A Text Book of Forest Tree Breeding*. ICAR.

Wright JW. 1976. *Introduction to Forest Genetics*. Academic Press.

Zobel BJ and Talbert J. 1984. *Applied Forest Tree Improvement*. John Wiley and Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Phytodiversity-concept, levels ecosystem	2
2.	Genetic diversity and differentiation-definition, characteristics and importance for tree breeding	3
3.	Genetic erosion. Techniques to assess genetic diversity	3
4.	Analysis of karyotypic variation	2
5.	Molecular approaches for assessing genetic diversity	3
6.	Inventory and monitoring biodiversity	3
7.	Sampling strategies for genetic diversity assessments sufficiency of sampling procedures	2
8.	Neutral allele model and optimal allocation of sampling efforts	3
9.	Methodsof sampling of genetic diversity	2
10.	Factors influencing levels of genetic diversity in woody plant species	2
11.	Conservation of genetic diversity conservation biology and invasive species	2
12.	Laws and policies	2
13.	Methods for maintenance of conservation: Gene banks, arboreta, botanical gardens, breeding populations as repositories of gene conservation	3
14.	Rare, threatened biodiversity, endangered and endemise plants	1
15.	Techniques for survey and assessment of endangered plants	3
16.	Rarity patterns and endemism	2
17.	Concept of island biogeography. Managing corridors and natural habitat fragments	2
18.	Monitoring and recovery plans for endangered plants	2
19.	Plant community reserves	2
20.	Managing wild flora tourism impacts and eco tourism and urban forestry of rare/ exotic plants	2
21.	Implications of rarity	2
	Total	48

I. Course Title : Biotechnology In Forestry

II. Course Code : FBT 508

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about different aspects of biotechnology in forestry

V. Theory

Unit I

Introduction. Cloning, need for cloning, problems with cloning. Traditional cloning techniques versus micro-propagation, prospects of micro-propagation in forestry. Techniques procedures and problems in micro propagation, case studies. Protocols for micro-propagation.Preconditioning of explants, surface sterilization, nutritional media, other environmental factors controlling micro-propagation, choice of explants for micro-propagation. Micro propagation of juvenile material. Micro propagation of mature trees. *In-vitro* propagation of plants with low sexual reproduction rates, miscellaneous application.

Unit II

Initiation and maintenance of callus. Organogenesis and somatic embryogenesis – factors influencing somatic embryogenesis-applications in forestry, Somatic seeds, encapsulation techniques. Somaclonal variation, genetic and epigenetic variation, exploitation in forestry. Cell suspension cultures. Anther and pollen cultures. Triploids through endosperm culture, embryo culture. Monoploid production by chromosome elimination. Applications of *In-vitro* fertilization, isolation, purification and culture of protoplasts, protoplast fusion and somatic hybridization. Cryopreservation, storage of plant genetic resouces. Production of secondary metabolites by cell cultures. Meristem culture, virus free plants.

Unit III

Genetic engineering – application in forestry Isozymes, restriction fragment length polymorphisms (RFLPs), randomly amplified polymorphic DNAs (RAPDs) and microsatellites. Genetic fingerprinting, Marker assisted selection. Different PCR techniques: their characteristics, with advantages and disadvantages.

Unit IV

Quantification of genetic diversity, genotype verification and delineation. Introduction of genes. Promoters and marker genes. disease resistance, herbicide tolerance and tolerance to salt and other stresses.

VI. Practical

- Introduction to tissue culture lab;
- Micropropagation: Aseptic techniques;
- Preparation of culture media,formulation of different culture media;
- Induction and maintenance of callus, regeneration of plants from callus, regeneration of plants from embryoids;
- Cell suspension culture;
- Anther and pollen culture. Quantification of tissue culture;
- Isolation and culture of protoplasts;
- Marker assisted RFLP in test trees;
- Study of PCR techniques used in tree improvement;
- Application of GENALEX 'bolt on' for excel, arlequin, PopGene and FSTAT for Wright's F-statistics and analysis of molecular variance (AMOVA).

VII. Suggested Reading

Bajaj YPS. 1986. *Biotechnology in Agriculture and Forestry*. Springer Verleg, New York.

Bonga JM and Durjan J. 1987. *Cell and Tissue Culture in Forestry Vol. I & II*. Martinus Nijost Publishers, Dordrecht.

Hainer R. 1996. *Biotechnology in Forest Tree Improvement*. (FAO Bulletin 1994) International Book Distributors. Dehra Dun.

Muchugi A, Kadu C, Kindt R, Kipruto H, Lemurt S, Olale K, Nyadoi P, Dawson I and Jamnadass R. 2008. *Molecular Markers for Tropical Trees, A Practical Guide to Principles and Procedures*. ICRAF Technical Manual no. 9. Dawson I and Jamnadass R. eds. Nairobi: World Agroforestry Centre.

Murphy TM and Thompson WF. 1988. *Molecular Plant Development*. Prentice Hall, Engleward, cliffe, New Jersey.

Russel GE. 1988. *Biotechnology of Higher Plants*. Intercept publishers, Nimborne, Dorset.

Russell Haines. 1994. *Biotechnology in Forest Tree Improvement with Special Reference to Developing Countries*. Food and Agriculture Organization of the United Nations, Rome.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Prospects of micro-propagation in forestry	1
2.	Techniques, procedures and problems in micro propagation – case studies	2
3.	Protocols for micro-propagation, choice of explants for micro-propagation preconditioning of explants, surface sterilization, nutritional media – other environmental factors controlling micro-propagation	2
4.	Micro propagation of juvenile material – Micro propagation of mature trees, *In-vitro* propagation of plants with low sexual reproduction rates, miscellaneous application	2
5.	Initiation and maintenance of callus, organogenesis and somatic embryogenesis, factors influencing somatic embryogenesis-applications in forestry, Somatic seeds, encapsulation techniques.	3
6.	Somaclonal variation, genetic and epigenetic variation, exploitation in forestry	2
7.	Cell suspension cultures, anther and pollen cultures, triploids through endosperm culture, embryo culture	2
8.	Monoploid production by chromosome elimination	1
9.	Applications of *In-vitro* fertilization	1
10.	Isolation, purification and culture of protoplasts, protoplast fusion and somatic hybridization	3
11.	Cryopreservation, storage of plant genetic resources.	1
12.	Production of secondary metabolites by cell cultures	2
13.	Meristem culture – virus free plants	1
14.	Genetic engineering – application in forestry,Isozymes, Restriction Fragment Length Polymorphisms (RFLPs), Randomly Amplified Polymorphic DNAs (RAPDs) and Microsatellites	3
15.	Genetic fingerprinting, marker assisted selection. Different PCR techniques: their characteristics, with advantages and disadvantages.	3
16.	Quantification of genetic diversity, genotype verification and delineation	2
17.	Introduction of genes, Promoters and marker genes. Disease resistance, herbicide tolerance and tolerance to salt and other stresses	2
	Total	33
	Practical	
1.	Introduction to tissue culture lab	1
2.	Micropropagation:Aseptic techniques, Preparation of culture media, Formulation of different culture media, explants inoculation, subculture and *in-vitro* rooting	4
4.	Induction and maintenance of callus, regeneration of plants from callus	
5.	Cell suspension culture	2
6.	Anther and pollen culture	2
7.	Isolation and culture of protoplasts	2
8.	Study of PCR techniques used in tree improvement. Testing of clonal fidelity through molecular markers	3
10.	Application of GENALEX ‘bolt on’ for Excel, Arlequin, PopGene and FSTAT for Wright’s F-statistics and Analysis of Molecular Variance (AMOVA)	2
	Total	16

I. Course Title : Clonal Forestry

II. Course Code : FBT 509

III. Credit Hours : 2+0

IV. Aim of the course

To provide information about genetics, conservation, biotechnological approaches for trees in clonal forestry system for higher biomass/ yield productivity

V. Theory

Unit I

Introduction to Clonal Forestry. History of clonal forestry. Clonal propagation. Clonal planting. Strategies for clonal forestry for higher productive potential.

Unit II

Juvenility and maturation, rejuvenation and maintainance, regulation of phase changes, markers of phase changes. Breeding strategies using vegetative propagation- selection and breeding for extreme genotypes. Physiological research for higher productivity of clonal forest. Field design, testing and evaluation of clones. Genetic gains from breeding with clonal option. Clonal conservation approaches- management of populations for genetic diversity and gain.

Unit III

Biotechnological approaches for clonal forestry, Plant tissue culture, micropropagation, Rejuvenation of tissues from mature trees, Testing of Clonal fidelity using molecular markers.

VI. Suggested Reading

Ahuja MR and Libby WJ. 1993. *Clonal Forestry I Conservation and Application*. Springer
Ahuja MR. 1992. *Micropropagation of Woody Plants*: Volume 41 (Forestry Sciences). Springer
Ahuja MR and Libby WJ. 1993. *Clonal Forestry II Genetics and Biotechnology*. Springer
Mandal AK and Gibson GL. 2002. *Forest Genetics and Tree Breeding*. CBS Publishers, New Delhi

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Introduction to clonal forestry; History of clonal forestry	2
2.	Clonal propagation	4
3.	Clonal planting, strategies for clonal forestry for higher productive potential	2
4.	Juvenility and Maturation, rejuvenation and maintainance, regulation of phase changes, markers of phase changes	3
5.	Breeding strategies using vegetative propagation- selection and breeding for extreme genotypes	4
6.	Physiological research for higher productivity of clonal forestry.	3
7.	Field design, testing and evaluation of clones	3
8.	Genetic gains from breeding with clonal option. Clonal conservation approaches- management of populations for genetic diversity and gain	4

Sr. No.	Topic	No. of Lecture(s)
9.	Biotechnological approaches for clonal forestry-plant tissue culture-micropropagation	3
10.	Rejuvenation of tissues from mature trees	2
11.	Testing of clonal fidelity using molecular markers	2
	Total	**32**

I. Course Title : Forest Ecophysiology

II. Course Code : FBT 510

III. Credit Hours : 2+1

IV. Aim of the course

To under stand dynamics of forest ecosystem and role of stress in forest productivity.

V. Theory

Unit I

Forest environment interactions, Forest ecosystems, Geographic and climatic factors. Environmental factors influencing forest growth and productivity. Sun and shade plants.

Unit II

Influence of temperature, water stress and nutrient availability and disturbance in the forest on tree growth and forest productivity.

Unit III

Dynamics of forest ecosystems, energy, productivity and biomass. Decomposition and nutrient cycling.

Unit IV

Stand structure and micro-climate, energy relationships canopy energy balance. Partitioning absorbed energy. Radiation penetration into and absorption by canopies. Air temperature and humidity in forests. Turbulent transfer process above forests.

Unit V

Transpiration and evapotranspiration from forest canopies. Estimation of ET.

Unit VI

Stress – avoidance and tolerance mechanisms. Temperature stress – low temperature stress – physiology of resistance to frost. Heat stress, heat injury, heat avoidance and tolerance mechanism. Radiation stress, mechanism of shade tolerance, water logging, physiology of resistance to water logging. Drought stress, salt and ion stress.

VI. Practical

- Morphological, anatomical and physiological variations between sun and shade plants;
- Estimation of leaf area, LAI;
- Estimation of biomass production of trees of different species;
- Estimation of microclimatic elements as influenced by stand structure;

- Estimation of evapotranspiration;
- Measurement of radiation in different types of forest and agroforestry systems.

VII. Suggested Reading

Kozlowski TT, Kramer PJ and Pallardy GS. 1991. *The Physiological Ecology of Woody Plants*. Academic Press, New York.

Kramer PJ. 1972. *Plant and Soil Water Relationships*. TMH Edition, Tata McGraw Hill Publ. Co., New Delhi.

Ksenzhek OS and Volkov AG. 1998. *Plant Energetics*. Academic Press, New York.

Lack AJ and Evans DE. 2001. *Plant Biology- Instant Notes*. Vina Books Pvt. Ltd., New Delhi.

Lambers H, Chaplin FS and Pons TL. 1998. *Plant Physiological Ecology*. Springer, New York

Larcher W. 2003. *Physiological Plant Ecology*. 4th edn, Springer-Verlag, Germany

Luttge U. 2008. *Physiological Ecology of Tropical Plants*. Springer-Verlag, Germany

Moore TC. 1989. *Biochemistry and Physiology of Plant Hormones*, 2nd ed. Springer Verlag, Berlin.

Taiz L and Zeiger E. 2007. *Plant Physiology*, 4th ed. Sinauer Associates Inc. Publishers, Sunderland.

Wilkins BM. 1984. *Advanced Plant Physiology*. ELBS/ Longman Pub. Co.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Forest environment interactions, forest ecosystems, geographic and climatic factors. Environmental factors influencing forest growth and productivity. Sun and shade plants	3
2.	Influence of temperature, water stress and nutrient availability and disturbance in the forest on tree growth and forest productivity	3
3.	Dynamics of forest ecosystems, energy, productivity and biomass. Decomposition and nutrient cycling	3
4.	Stand structure and micro-climate, energy relationships, Canopy energy balance. Partitioning absorbed energy	3
5.	Radiation penetration into and absorption by canopies. Air temperature and humidity in forests. Turbulent transfer process above forests	3
6.	Transpiration and evapotranspiration from forest canopies, Estimation of ET	3
7.	Stress – avoidance and tolerance mechanisms	2
8.	Drought stress	3
9.	Temperature stress, low temperature stress, physiology of resistance to frost	3
10.	Heat stress, heat injury, heat avoidance and tolerance mechanism	3
11.	Radiation stress – mechanism of shade tolerance	1
12.	Water logging, physiology of resistance to water logging	1
13.	Salt and ion stress	2
	Total	**33**
	Practical	
1.	Morphological, anatomical and physiological variations between sun and shade plants	3

Sr. No.	Topic	No. of Lecture(s)
2.	Estimation of leaf area, LAI	2
3.	Estimation of biomass production of trees of different species	3
4.	Estimation of microclimatic elements as influenced by stand structure	3
5.	Estimation of evapotranspiration	2
6.	Measurement of radiation in different types of forest and agroforestry systems	3
	Total	**16**

I. Course Title : Physiology of Woody Plants

II. Course Code : FBT 511

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about the concepts of physiology for understanding its use in increasing productivity of forest stands.

V. Theory

Unit I

Introduction, Tree physiology. Growth, phases of growth, growth curve, factors affecting growth.- Wood formation.

Unit II

Plant cell as a structural and functional unit. Organization of cells and tissues, morphogenesis.

Unit III

Structure of leaves, stem wood, bark and roots in trees. Functions and process in plant growth and development.

Unit IV

Photosynthesis, structure of photosynthetic tissues and organs, enzyme, energetics and factors influencing photosynthesis. Photorespiration, its mechanisms and significance, factors affecting photorespiration.

Unit V

Respiration, mechanisms, enzymes, energetics and factors influencing respiration. Respiratory quotient.

Unit VI

Water relations of trees, absorption, ascent of sap. Translocation of solutes, phloem loading and phloem transport. Transpiration, mechanisms and factors influencing, regulating transpiration, antitranspirants.

Unit VII

Mineral nutrition. Mineral salt absorption and translocation, deficiency and toxicity of mineral nutrients. Diagnosis of mineral deficiency.

Unit VIII

The enzymes, nomenclature and classification, structure and compositioned. Mode of action. Phytohormones, auxins, GA, cytokinins, ABA, ethlynene. Biosynthesis and biochemical activity of plant hormones. Synthetic plant growth regulators. Growth retardants.

Unit IX

Nitrogen fixing trees, Nitrogen metabolism. N_2 fixation, physical and biological. Nitrogen assimilation, Amino acid and protein synthesis.

Unit X

Fat metabolism. Carbohydrate metabolism.

VI. Practical

- Preparation of growth curves of different tree seedlings;
- Study of structure of leaves;
- Measurement of photosynthesis;
- Observing structure of plant cells and leaves in C3 and C4 species;
- Studying stomata in different tree species and working out stomatal frequency;
- Measurement of stomatal size in different tree species;
- Estimation of transpiration rates in different trees;
- Isolation and estimation of chlorophyll;
- Observing xylem vessel size variation in tree species;
- Estimation of plant water status by different methods;
- Nutrient deficiency symptoms in tree seedlings.

VII. Suggested Reading

Dreyer E. 2011. *Forest Tree Physiology*. University of Minnesota, Elsevier

Kramer PJ and Kozlowsky TT. 1979. *Physiology of Woody Plants*. Academic Press.

Kramer PJ. 1972. *Plant and Soil Water Relationships*. TMH Edition, Tata McGraw Hill Publ. Co., New Delhi.

Ksenzhek OS. and Volkov AG. 1998. *Plant Energetics*. Academic Press, New York.

Lack AJ and Evans DE. 2001. *Plant Biology- Instant Notes*. Vina Books Pvt. Ltd., New Delhi.

Larcher W. 2003. *Physiological Plant Ecology*. 4th edn, Springer-Verlag, Germany

Luttge U. 2008. *Physiological Ecology of Tropical Plants*. Springer-Verlag, Germany

Malik CP and Srivastava. 2015. *Textbook of Plant Physiology*. Kalyani Publishers, Mumbai

Moore TC. 1989. *Biochemistry and Physiology of Plant Hormones*. 2nd ed. Springer-Verlan, Berlin.

Noggle RG. and Fritz GJ. 2010. *Introductory plant physiology*. Sinauer Associates Inc. Publishers, Sunderland

Pallardy HG. 2008. *Physiology of Woody Plants*. Elsevier, Amsterdam

Taiz L and Zeiger E. 2007. *Plant Physiology* 4th ed. Sinauer Associates Inc. Publishers, Sunderland.

Zimmerman MH and Brown CL. 1971. *Tree structure and Function*, Springer Verlag.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction, Tree physiology, growth, phases of growth, growth curve factors affecting growth, wood formation	3
2.	Plant cell as a structural and functional unit. Organization of cells and tissues morphogenesis	2

Sr. No.	Topic	No. of Lecture(s)
3.	Structure of leaves, stem wood, bark and roots in trees. Functions and process in plant growth and development	4
4.	Photosynthesis, structure of photosynthetic tissues and organs, enzyme, energetics and factors influencing photosynthesis. Photorespiration, its mechanisms and significance, factors affecting photorespiration	4
5.	Respiration, mechanisms, enzymes, energetics and factors influencing respiration. Respiratory quotient	3
6.	Water relations of trees, absorption, ascent of sap. Translocation of solutes – Phloem loading and phloem transport. Transpiration, Mechanisms and factors influencing,regulating transpiration, antitranspirants	4
7.	Mineral nutrition, Mineral salt absorption and translocation, deficiency and toxicity of mineral nutrients. Diagnosis of mineral deficiency	3
8.	The enzymes, nomenclature and classification, structure and composition – Mode of action. Phytohormones – auxins, GA, cytokinins, ABA, ethlynene biosynthesis and biochemical activity of Plant hormones. Synthetic plant growth regulators. Growth retardants	3
9.	Nitrogen fixing trees, Nitrogen metabolism. N_2 fixation, physical and biological. Nitrogen assimilation, Amino acid and protein synthesis.	3
10.	Fat metabolism. Carbohydrate metabolism	3
	Total	32

Practical

1.	Preparation of growth curves of different tree seedlings	2
2.	Study of structure of leaves. Observing structure of plant cells and leaves in C3 and C4 species	2
3.	Measurement of photosynthesis	2
4.	Studying stomata in different tree species and working out stomatal frequency and size	1
5.	Estimation of transpiration rates in different trees	2
6.	Isolation and estimation of chlorophyll	1
7.	Observing xylem vessel size variation in tree species	1
8.	Estimation of plant water status by different methods	3
9.	Nutrient deficiency symptoms in tree seedlings	2
	Total	**16**

I. Course Title : Breeding for Insect Pest and Disease Resistance in Trees

II. Course Code : FBT 512

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about mechanisms of disease and insect pest resistance in trees, breeding methodology to incorporate disease and insect pest resistance.

V. Theory

Unit I

Need for disease resistance in forest trees, Process of infection. Variability in plant pathogens. Types of resistance. Inheritance of resistance. Disease resistance mechanisms in trees, Clonal resistance. Disease resistance breeding techniques. Techniques of isolating resistant genes; developing disease resistant transgenic plants.

Unit II

History and importance of insect pest resistance, types and mechanism of resistance. Insect-tree relationships. Basis of resistance: Induced resistance and acquired resistance. Defense mechanisms against insects. Factors affecting tree pest resistance. Breeding for insect resistance.

VI. Practical

- Disease progression in relation to resistance, disease resistance in clonal plantations and seed orchards, hypersensitivity and its mechanisms, disease resistance screening;
- Screening for insect pest resistance; chemical and morphological characterization of susceptible/ resistance tree species;
- Defence strategies of woody plants.

VII. Suggested Reading

Dube HC. 2014. *Modern Plant Pathology*, Second Edition. Agribios, Jodhpur (India).

Harsh NS. 2012. *Disease Resistance in Genetic Material in Tree Improvement Programme*. Lambert Acad. Publications.

Heybroek HM, Stephan BR and Weissenberg KV. 1990. *Resistance to Diseases and Pests in Forest Trees*. IBD, Dehra Dun (India).

Nair KSS, Sharma JK and Varma RV. 1996. *Impact of Diseases and Insect Pest in Forest Trees*.

Parker J. 2008. *Molecular Aspects of Plant Disease Resistance*. Ann. Pl. Rev.,. 34. Blackwell Publications UK.

Ross Wylie F and Martin R Speight. 2012. *Insect Pests in Tropical Forestry* (2nd Ed.). CABI *Tropical Forests*.

Van der Plank JE. 1984. *Disease Resistance in Plants*. Academic Press Inc., New York.

Van der Plank JE. 1982. *Host Pathogen Interactions in Plant Disease*. Academic Press Inc., New York.

Willium M Ciesla. 2010. *Forest Entomology-A Global Perspective*. Wiley-Blackwell.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Need for disease resistance in forest trees	1
2.	Process of infection, variability in plant pathogens	3
3.	Inheritance of resistance	3
4.	Disease resistance mechanisms in trees	2
5.	Clonal resistance	1
6.	Disease resistance breeding techniques	3
7.	Types of resistance techniques of isolating resistant genes	3
8.	Developing disease resistant transgenic plants	2
9.	History and importance of insect pest resistance	1

Sr. No.	Topic	No. of Lecture(s)
10.	Types and mechanism of resistance	2
11.	Insect-tree relationships	3
12.	Basis of resistance: Induced resistance and acquired resistance. Defence mechanisms against insects	4
13.	Factors affecting tree pest resistance	2
14.	Breeding for insect resistance	2
	Total	32

Practical

1.	Disease progression in relation to resistance	3
2.	Disease resistance in clonal plantations and seed orchards	2
3.	Hypersensitivity and its mechanisms	2
4.	Disease resistance screening	3
5.	Screening for insect pest resistance	2
6.	Chemical and morphological characterization of susceptible/ resistance tree species	2
7.	Defence strategies of woody plants	2
	Total	16

I. Course Title : Tree Seed Technology

II. Course Code : FBT 513

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and develop understanding about tree seed development, harvesting, processing, storage, dormancy, germination of tropical, sub-tropical and temperate species, their testing and certification.

V. Theory

Unit I

Trends and development in tropical, sub-tropical and temperate forestry and their influence on seed demand. Seed problems, limiting factors in tree propagation and afforestation.

Unit II

Ecological fruit and seed types – seasonality and periodicity of flowering and fruiting. Seed structure and chemical composition development and maturation germination breakdown of storage products endogenous hormonal regulation effect of stimulators and inhibitors. Dormancy its causes and breakage specific problems of seeds of woody plants.

Unit III

Determining optimal harvest maturity indices. Methods of seed collection and processing. Storage methods – loss of viability during storage. Dormancy and pre-treatment and seed testing techniques.

Unit IV

Quality seed production technologies – Seed stand/ seed production area, pollen management in seed orchards. Seed transfer guidelines. Seed certification and legislation.

Unit V

Factors affecting seed longevity. Pre-storage treatment. Physiological change during ageing. Viability and vigor. Storage of orthodox, recalcitrant and pre-storage intermediate seeds, Fumigation and seed treatment.

Unit VI

Seed fortification. Seed pelleting.

VI. Practical

- Identification of forest seed;
- Seed sampling, Seed quality testing- purity, viability and germination;
- Collection and processing of seeds/ fruit. Different storage methods;
- Pretreatment of seed;
- Seed fortification;
- Seed pelleting.

VII. Suggested Reading

Dutta M and Saini GC. 2009. *Advances in Forestry Research in India*, Vol. XXX. *Forest Tree Improvement and Seed Technology*. International Book Distributors.
Khullar P, Thapliyal RC, Beniwal BS, Vakshasya and Sharma A. 1991. *Forest Seeds. ICFRE.*
Lars H Schmidt. 2000. *Guide to Handling of Tropical and Subtropical Forest Seeds*. Danida Forest Seed Centre.
Mema NP. 1989. *Principles of Seed Certification and Testing.* Allied Publ.
Negi SS. 2008. *Forest Tree Seeds*. International Book Distributers
Ram Prasad and Kandya RK. 1992. *Handling of Forestry Seeds in India.*Associated Publ.
Vanangamudi K. 2007. *Advances in Seed Science and Technology*, Volume IV. Agrobios (India).
Vanangamudi K. 2013. *Advances in Seed Science and Technology*, Volume III. Agrobios (India).
William RL. 1985. *A Guide to Forest Seed Handling with Reference to the Tropics.* FAO.
Zobel B and Talbert J. 1984. *Applied Forest Tree Improvement.* John Wiley & Sons.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Trends in seed demand. Seed problems, limiting factors in tree propagation and afforestation	1
2.	Ecological fruit and seed types – seasonality and periodicity of flowering and fruiting	3
3.	Seed structure and chemical composition – development and maturation	2
4.	Germination – breakdown of storage products endogenous hormonal regulation	2
5.	Effect of stimulators and inhibitors dormancy – its causes and breakage	2
6.	Determining optimal harvest maturity indices	2
7.	Methods of seed collection and processing, storage methods loss of viability during storage	2
8.	Dormancy and pre-treatment	2

Sr. No.	Topic	No. of Lecture(s)
9.	Seed testing techniques	2
10.	Quality seed production technologies seed stand/ seed production area	2
11.	Pollen management in seed orchards	2
12.	Seed transfer guidelines	2
13.	Seed certification and legislation	2
14.	Factors affecting seed longevity. Pre-storage treatment. Physiological change during ageing. Viability and vigor	3
15.	Storage of orthodox, recalcitrant and pre-storage intermediate seeds, Fumigation and seed treatment	2
16.	Seed fortification, seed pelleting	2
	Total	33

Practical

Sr. No.	Topic	No. of Lecture(s)
1.	Identification of forest seed	1
2.	Collection and processing of seeds/ fruit, different storage methods	2
3.	Seed sampling. Seed quality testing- purity, viability and germination	7
4.	Pretreatment of seed	2
5.	Seed fortification	2
6.	Seed pelleting	2
	Total	16

Course Title with Credit Load
Ph.D. (Forestry) in Forest Biology and Tree Improvement

Course Code		Course Title	Credit Hours
		Major Courses	
FBT 601*	I	Special Topics in Tree Improvement	2+1
FBT 602	II	Forest Genetics and Tree Breeding	2+0
FBT 603*	I	Biometrical Genetics	2+1
FBT 604	II	Forest Tree Reproduction	2+1
FBT 605	I	Molecular Genetics of Forest Trees	2+1
FBT 606	II	Genetics of Forest Ecosystems and Conservation Biology	3+0
FBT 607	I	Tree Physiology and Forest Productivity	1+1
FBT 608	II	Tree Seed Management	2+1
		Minor Courses	
		Courses from Silviculture and Agroforestry or Forest Products and Utilization	06
		Supporting Courses	
FOR 610*	I	Research Methodology in Forestry	2+1
FOR 611	II	Research and Publication Ethics	1+1
FBT 691*	I/ II	Doctoral Seminar	1+0
FBT 692*	I/ II	Doctoral Seminar	1+0
	ii)	Thesis Research	
FBT 699		Doctoral Research	0+75

*Compulsory Core Courses

Course Contents
Ph.D. (Forestry) in Forest Biology and Tree Improvement

I. Course Title : Special Topics in Tree Improvement

II. Course Code : FBT 601

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding among students in application of Mendelian principles to forest trees and integration of physiological and molecular techniques for tree improvement programmes.

V. Theory

Unit I

Mendelian concepts as applied to forest trees. Cytological and chromosomal systems of forest trees. Cytoplasmic inheritance in trees. Colchiploid and mutation breeding for forest trees.

Unit II

Tree domestication for small-scale farmers: needs, criteria and selection methods. Choosing the right tree. Participatory rural appraisal approaches. Ethnobotanical methods. Species priority setting procedures. Value chain analysis. Participatory tree domestication approach.

Unit III

Physiological basis of tree improvement. Pollution responses of trees. Pollen handling and hybridization techniques in forest trees. Tissue culture of trees.

Unit IV

Molecular genetics as applied to forest trees, recent trends in tree improvement, somatic hybrids, transformation, gene sequencing. Inheritance of monoterpene composition in conifers.

Unit V

Indirect selection for improvement of desired traits, molecular markers. Juvenile traits and their role in genetic evaluation in tree improvement programmes.

Unit VI

Geographic variation in trees, evolution and gene flow. Exploration and conservation of gene resources of trees. Dioecism and moneocism in trees.

VI. Practical

- Cytology of pine root tips, kryotypic analysis;
- Mutagenic treatments with colchicine and MH;
- Tissue culture of organs and transformation experiments, resin tapping;
- Observation of trees for menoecium and dioecium.

VII. Suggested Reading

Ramawat KG, Merillon JM and Ahuja MR. 2014. *Tree Biotechnology*. CRC Press.
Schnell RJ and Pridarshan PM. 2012. *Genomics of Tree Crops*, Springer.
White TL, Adams WT and Neale DB. 2007. *Forest Genetics*. CABI.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction	1
2.	Mendelian concepts as applied to forest trees	1
3.	Tree domestication, selection methods, ethnobotanical methods	2
4.	Value chain analysis, Participatory tree domestication approach	2
5.	Cytological and chromosomal systems of forest trees	2
6.	Cytoplasmic inheritance in trees	1
7.	Colchiploid and mutation breeding for forest trees	2
8.	Pollen handling and hybridization techniques in forest tree	1
9.	Physiological basis of tree improvement	2
10.	Pollution responses of trees	2
11.	Tissue culture of trees	2
12.	Somatic hybrids	1
13.	Genetic transformation	2
14.	Gene sequencing	2
15.	Inheritance of monoterpene composition in conifers	1
16.	Indirect selection for improvement of desired traits, molecular markers. Juvenile traits and their role in genetic evaluation in tree improvement programmes	4
17.	Geographic variation in trees	1
18.	Evolution and gene flow	1
19.	Exploration and conservation of gene resources of trees	1
20.	Dioecism and moneocism in trees	2
	Total	33
	Practical	
1.	Cytology of softwood/ harwood spps	4
2.	Mutagenic treatments with colchicine and MH	3
3.	Tissue culture of organs and transformation experiments	7
4.	Observation of trees for monoecium and dioecium	2
	Total	16

I. Course Title : Forest Genetics and Tree Breeding

II. Course Code : FBT 602

III. Credit Hours : 2+0

IV. Aim of the course

To develop understanding among students about methodologies involved in the study of gene flow of forest tree through pollen, seed, development of hybrids and molecular breeding.

V. Theory

Unit I

Taxonomy and phylogenetic studies. Assessment of genetic diversity, gene conservation, breeding populations: long term and short term, pollen collection storage, extension, theories of pollen dispersal, mating designs. Polygenic inheritance, genetics of heterosis, overcoming incompatibility, hybrid embryo rescue and studies in hybrid development in forest trees.

Unit II

Molecular breeding- constructing molecular map. Integrating genetic, physical and molecular maps. Diversity assessment and phylogenetic analysis. Molecular tagging of genes/ traits. Selected examples on marker assisted selection of qualitative and quantitative traits. Application of molecular markers and genomic tools for the genetic enhancement.

VI. Suggested Reading

Khosla PK. 1981. *Advances in Forest Genetics*. Ambika Publ., New Delhi.
Mandal AK and Gibson GL. (Eds.). 1997. *Forest Genetics and Tree Breeding*. CBS.
Nanson A. 2004. *Genetics of Forest Tree Breeding*. Agronomic Press.
Schnell RJ and Pridarshan PM. 2012. *Genomics of Tree Crops*, Springer.
Surendran C, Sehgal RN and Parmathama M. (Eds.). 2003. *A Text Book of Forest Tree Breeding*. ICAR.
Suzuki D, Gryfiths AJF, Miller JH and Lewontin RC. 1986. *An Introduction to Genetic Analysis*.
Wright JW. 1976. *Introduction to Forest Genetics*. Academic Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Taxonomy and phylogenetic studies	3
2.	Assessment of genetic diversity and gene conservation	3
3.	Breeding populations: long term and short term	3
4.	Pollen collection storage, extension, theories of pollen dispersal	3
6.	Polygenic inheritance	4
7.	Genetics of heterosis	2
8.	Overcoming incompatibility, hybrid embryo rescue and studies in hybrid development in forest trees	2
9.	Molecular breeding- constructing molecular map. Integrating genetic, physical and molecular maps	5
11.	Molecular tagging of genes/ traits	3
12.	Application of molecular markers and genomic tools for the genetic enhancement	2
13.	Selected examples on marker assisted selection of qualitative and quantitative traits	2
	Total	**32**

I. Course Title : Quantitative Forest Genetics

II. Course Code : FBT 603

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of principles of biometrical genetics and utility of various biometrical techniques in tree improvement programmes.

V. Theory

Unit I

Concepts inquantitative genetics, quantitative inheritance, historical aspects, Galton (1869) methods for studying quantitative traits, qualitative and quantitative traits and their inheritance, property of nuclear born genes (segregation and linkages). Linkage between major gene and polygenes. Evidence that quantitative trait is inherited in Mendalian Fashion. Nilsson Ehle (1908) multiple factor hypothesis. East (1916) experiment on *Nicotiana longifera*.

Unit II

Genetic components of continuous variation gene models (additive, dominance, epistasis) features of additive gene action, features of non-additive gene action, genetic variance in F_2 population in various gene models. Important principles established by NCSU (North Carolina State University) for forest Tree Improvement, Origin of variation, estimation of hereditary parameters, variance derivation in F_2 and backcrosses. Genotype X environment interaction, its measurement and significance. Concepts of heritablility and genetic advance. Random mating in forest trees, their population structure and response to selection.

Unit III

Quantitative genetics in relation to efficient breeding methodology – partitioning of means and variances, simple scaling and joint scaling tests. Line X tester analysis and diallel analysis mating designs in tree improvement, incomplete pedigree design and complete pedigree design.

Unit IV

Usefulness of biometrical techniques. Assessment of variability, variance analysis, metroglymph analysis, D^2. Statistic. Aids to selection correlation, path analysis, discriminant function. Aids to choice of parents: Assessment of adaptability, stability analysis, software in forest genetic analysis and their interpretation.

Unit V

Molecular diversity analysis, methods for mapping QTL.

VI. Practical

- Genotypic and phenotypic variance in forest trees;
- Detection of linkage in coupling;
- Proof that gene and genotypic frequencies remain constant in random mating populations;
- Stability analysis- Eberhart and Russel Model (1966)- Perkins and Jinks Model (1971);
- Problems on demonstrating the effects of selection, mutation, migration and genetic drift in random mating population through graphs. Simple scaling tests. Joint scaling tests;
- Heritability estimation (Analysis of variance, parent offspring correlation and regression).Heritability in narrow sense estimation;
- Line X Tester analysis;
- Diallel analysis.
- Calculation of genotypic and phenotypic correlations;

- Path analysis;
- Discriminant function. D^2 Statistics;
- Principal component analysis;
- Diversity analysis based on RAPD/ SSR.

VII. Suggested Reading

Mather K and Jinks JL. 1971. *Biometrical Genetics*. Champman and Hall, London.
Singh RK and Chaudhary BD. 1985. *Biometrical Methods in Quantitative Genetical Analysis*. Kalyani Publishers, New Delhi.
White TL, Adams WT and Neale DB. 2007. *Forest Genetics*. CABI.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Concepts inquantitative genetics, quantitative inheritance, historical aspects	1
2.	Galton (1869) methods for studying quantitative traits, qualitative and quantitative traits and their inheritance, property of nuclear born genes (segregation and linkages)	2
3.	Linkage between major gene and polygenes. Evidence that quantitative trait is inherited in Mendalian Fashion. Nilsson Ehle (1908) multiple factor hypothesis. East (1916) experiment on *Nicotiana longifera*	2
4.	Genetic components of continuous variation gene models (additive, dominance, epistasis) features of additive gene action, features of non-additive gene action, genetic variance in F_2 population in various gene models	3
5.	Important principles established by NCSU (North Carolina State University) for forest Tree Improvement, Origin of variation, estimation of hereditary parameters, variance derivation in F_2 and backcrosses. Genotype X environment interaction, its measurement and significance	3
6.	Concepts of heritablility and genetic advance.Random mating in forest trees, their population structure and response to selection	1
7.	Quantitative genetics in relation to efficient breeding methodology – partitioning of means and variances, simple scaling and joint scaling tests	2
8	Incomplete pedigree design and complete pedigree design. Line X tester analysis and diallel analysis mating designs in tree improvement	2
9.	Usefulness of biometrical techniques. Assessment of variability, variance analysis	2
10.	metroglymph analysis	2
11.	D^2. Statistic	2
12.	Aids to selection correlation, path analysis, discriminant function	2
13.	Aids to choice of parents: Assessment of adaptability	2
14.	Stability analysis	2
15.	Software in forest genetic analysis and their interpretation	2
16.	Molecular diversity analysis, methods for mapping QTL	2
	Total	32

Sr. No.	Topic	No. of Practical(s)
	Practical	
1.	Genotypic and phenotypic variance in forest trees	1
2.	Detection of linkage in coupling. Eberhart and Russel Model (1966)- Perkins and Jinks Model (1971	1
3.	Proof that gene and genotypic frequencies remain constant in random mating populations	1
4.	Stability analysis-	1
5.	Problems on demonstrating the effects of selection, mutation, migration and genetic drift in random mating population through graphs	2
6.	Simple scaling tests. Joint scaling tests	1
7.	Heritability estimation (Analysis of variance, parent offspring correlation and regression).Heritability in narrow sense estimation	1
8.	Line X Tester analysis	1
9.	Diallel analysis	1
10.	Calculation of genotypic and phenotypic correlations	1
11.	Path analysis	1
12.	Discriminant function.D^2 Statistics	1
13.	Principal component analysis	1
14.	Diversity analysis based on RAPD/ SSR	2
	Total	16

I. Course Title : Forest Tree Reproduction

II. Course Code : FBT 604

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about phenology, phenodynamics breeding behaviour pollination biology and breeding systems in forest trees.

V. Theory

Unit I

Reproductive biology of gymnosperms and angiosperms, Reproduction and population genetic structure, population dynamics. Floral morphology, floral initiation and breeding systems. Flowering manipulation. Reproductive abnormalities.

Unit II

Pollination, biology, pollination ecology of tropical and temperate forest tree species, plant-pollination interactions. Pollinator energetic and nectar production.

Unit III

Genetic consequences of variation in reproductive biology. Pollen biotechnology for improved production.

Unit IV

Gene expression during pollen development. Pollination efficiency of insects. Self-incompatibility.

VI. Practical

- Phenological studies in forest trees;
- Nectar collection and analysis;
- Pollination trapling distances;
- Foraging behaviour;
- Pollinator identification and visitation.

VII. Suggested Reading

Barrett SCH. 2006. *Ecology and Evolution of Flowers.* [electronic resource]. (Eds.) L.D. Harder SCH. Barrett. Oxford Univ. Press, New York, U.S.A.

Bawa KS and Hadley M. 1990. *Reproductive Ecology of Tropical Forest Plants.* UNESCO Man and Biosphere series.

Briggs and Walters S. 1984. *Plant Variation and Evolution.*

Cláudia Inês da Silva and Helena Maura Torezan Silingardi. 2006. *Reproductive Biology of Tropical Plants.* International Commission on Tropical Biology and Natural Resources. Encyclopedia of Life Support Systems (EOLSS).

FAO. 1985. *Forest Tree Improvement,* FAO Publication.

Khosla PK. 1981. *Advances in Forest Genetics.* Ambika Publ., New Delhi.

Mandal AK and Gibson GL. (Eds.). 1997. *Forest Genetics and Tree Breeding.* CBS.

Sedgley M and Griffin AR. 1989. *Sexual Reproduction of Tree Crops.* Academic Press.

Spencer CH, Barrett, Robert I, Colautti and Christopher G Eckert. 2007. *Plant Reproductive Systems and Evolution during Biological Invasion.* Wiley Online Library.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Reproductive biology of gymnosperms and angiosperms	2
2.	Reproduction and population genetic structure, population dynamics	2
3.	Floral morphology, floral initiation and breeding systems	4
4.	Flowering manipulation	2
5.	Reproductive abnormalities	2
6.	Pollination, biology, pollination ecology of tropical and temperate forest tree species, plant-pollination interactions	5
7.	Pollinator energetic and nectar production	2
8.	Genetic consequences of variation in reproductive biology	2
9.	Pollen biotechnology for improved production	2
10.	Gene expression during pollen development	2
11.	Pollination efficiency of insects	2
12.	Self-incompatibility	2
	Total	32
	Practical	
1.	Phenological studies in forest trees.	4
2.	Pollination trapling distances.	2
3.	Nectar collection and analysis.	4
4.	Foraging behaviour.	3
5.	Pollinator identification and visitation.	3
	Total	16

I. Course Title : Molecular Genetics of Forest Trees

II. Course Code : FBT 605

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding among students about molecular markers, biochemical markers, gene mapping, transgenics in forest trees.

V. Theory

Unit I

Biochemical markers (Isozymes and Monoterpenes). Molecular markers – Non-PCR based (RFLP) and PCR based (RAPD, ISSR, SSR, AFLP, SNP, etc.). Application in forestry – quantification of genetic diversity. Marker assisted selection. Genetic maps of selected forest trees.

Unit II

DNA sequencing. Structural genomics. Functional genomics. Transcriptomics. Proteomics. Metabolomics.

Unit III

Recombinant DNA Technology, Transgenics, Vectors,. Gene transfer strategies – direct and indirect. Molecular characterization of transformants. Application of transgenics in forestry.

VI. Practical

- Isolation of DNA, RNA from forest tree species;
- Isozyme analysis;
- Use of molecular markers and RAPD and RFLP for clonal identification;
- *Agrobacterium* mediated gene transfer;
- Preparation of linkage maps.

VII. Suggested Reading

Brown CM, Campbell I and Preist FG. 2005. *Introduction to Biotechnology*. Panama Publishers.
Chawla HS. 2004. *Introduction to Plant Biotechnology*. Kalyani Publishers.
Kole C 2007. *Genome Mapping and Molecular Breeding in Plants*. Springer.
Schnell RJ and Pridarshan PM. 2012. *Genomics of Tree Crops*. Springer.
Singh BD. 2006. *Biotechnology – Expanding Horizons*. Kalyani Publishers.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Biochemical markers (Isozymes and Monoterpenes)	2
2.	Molecular markers – Non-PCR based (RFLP) and PCR based (RAPD, ISSR, SSR, AFLP, SNP, etc.)	5
3.	Application in forestry – quantification of genetic diversity	2
4.	Marker assisted selection. Genetic maps of selected forest trees	4
5.	DNA sequencing	2
6.	Structural genomics, functional genomics	4
7.	Transcriptomics, proteomics, metabolomics	4
8.	Recombinant DNA Technology, Transgenics, Vectors	4

Sr. No.	Topic	No. of Lecture(s)
9.	Gene transfer strategies – direct and indirect	3
10.	Molecular characterization of transformants. Application of transgenics in forestry	2
	Total	32

Practical

1.	Isozyme analysis	2
2.	Isolation of DNA, RNA from forest tree species	2
3.	Use of molecular markers and RAPD, SSR and RFLP for clonal identification	6
4.	*Agrobacterium* mediated gene transfer	4
5.	Preparation of linkage maps	2
	Total	16

I. Course Title : Genetics of Forest Ecosystems and Conservation Biology

II. Course Code : FBT 606

III. Credit Hours : 3+0

IV. Aim of the course

To make the students understand about the ecological genetics, markers and sampling in ecological genetics, genetic diversity and differentiation, gene flow and mating system, forest ecosystems, physiology of woody plants and forests as biological community.

V. Theory

Unit I

What is ecological genetics, uses of ecological genetics, markers and sampling in ecological genetics, genetic diversity and differentiation, gene flow and mating system, intraspecific phylogenies and phylogeography, speciation and hybridization.

Unit II

The ecological niche, adaptations, genetic systems, adaptive strategies, forest ecosystems, how man affects forest ecosystems manmade forest ecosystems.

Unit III

Carbon sequestration consumption and export – carbon balance in trees – canopy photosynthesis – Transport and partitioning. Factors influencing net photosynthesis in trees. Relationship between the CO_2 compensation point and carbon fixation efficiency in trees. Physiology of formation of early and late woods-resource sharing in mixed agroforestry system.

Unit IV

Evapo-transpiration – factors affecting evapo-transpiration potential evapo-transpiration. Moisture stress – osmotic adjustment stomatal response to moisture stress water use efficiency drought tolerance.

Unit V

Forest as biological community, Amplification of conceptual and quantitative models of variation in trees.Changes in gene frequencies genetics and theory of selections adaptations and conservation. Gene flow and genetic drift, polymorphism. Population structure and migration.

Unit VI

Conservation biology: Introduction, Conservation biology—past and present. Biodiversity. Defining and measuring biological diversity. Threats to biodiversity. Computing biological diversity. Biological hot spots. Social value and the role of people in conservation. Ecosystem functions and services. Habitat destruction. Habitat fragmentation and landscape changes. Over harvesting. Invasive species impacts. Climate change. Population viability analysis. Application of population ecology to conservation biology for fauna and flora. Population and conservation genetics practical examples in conservation of plants and animals. Landscape ecology and conservation practices. Conservation planning and priorities. Single and Multi species conservation strategies. Endangered species management. Restoration and species recovery planning. Community biodiversity management. Strategic species concepts (Keystone species, Indicator species, Umbrella and flagship species) concept of sustainable development.

VI. Suggested Reading

Klaus Stern and Laurence Roche. 1974.*Genetics of Forest Ecosystems*.New York a.o. Springer-Verl.

Kozlowski TT. 1971. *Growth and Development of Trees*. Vol. I. Academic Press.

Kramer PJ and Kozlowshi TT. 1979. *Physiology of Woody Plants*. Academic Press.

Larcher W. 1980. *Physiological Plant Ecology*. Springer-Verlag.

Lowe A, Harris S and Ashton P. 2004. *Ecological Genetics: Design, Analysis and Application* Oxford: Blackwell Publishing.

Raghavendra AS. 1991. *Physiology of Trees*. John Wiley & Sons.

Weathers. 2013. *Fundamentals of Ecosystem Science*. M/s. International Books and Periodicals Supply Service, Pitampura, Delhi.

Zimmerman RH. 1972. *Juvenility and Flowering in Woody Plants: A Review. Hort. Science* 7(5): 447-455.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Ecological genetics, uses of ecological genetics, markers and sampling in ecological genetics	2
2.	Genetic diversity and differentiation, gene flow and mating system	2
3.	Intraspecific phylogenies and phylogeography, speciation and hybridization	2
4.	The ecological niche, adaptations.	1
5.	Genetic systems, adaptive strategies, forest ecosystems	2
6.	How man affects forest ecosystems manmade forest ecosystem	1
7.	Carbon sequestration consumption and export – carbon balance in trees	2
8.	Canopy photosynthesis – Transport and partitioning	1
9.	Factors influencing net photosynthesis in trees	1
10.	Relationship between the CO_2 compensation point and carbon fixation efficiency in trees	1

Sr. No.	Topic	No. of Lecture(s)
11.	Physiology of formation of early and late woods	2
12.	Resource sharing in mixed agroforestry system	2
13.	Evapo-transpiration, factors affecting evapo-transpiration, Potential evapo-transpiration	2
14.	Moisture stress, osmotic adjustment, stomatal response to moisture stress	2
15.	Water use efficiency, drought toleranc	1
16.	Forest as biological community	1
17.	Amplification of conceptual and quantitative models of variation in trees	1
18.	Changes in gene frequencies, genetics and theory of selections, adaptations and conservation	1
19.	Gene flow and genetic drift, polymorphism, population structure and migration	1
20.	Introduction, Conservation biology, past and present	1
21.	Biodiversity concepts. Measuring biological diversity. Threats to biodiversity	2
22.	Computing biological diversity. Biological hot spots	1
23.	Social value and the role of people in conservation	1
24.	Ecosystem functions and services	1
25.	Habitat destruction. Habitat fragmentation and landscape changes. Over harvesting. Invasive species impacts	2
26.	Climate change. Population viability analysis	1
27.	Application of population ecology to conservation biology: for fauna and flora	2
28.	Population and conservation genetics: practical examples in conservation of plants and animals	1
29.	Landscape ecology and conservation practices. Conservation planning and priorities	2
30.	Single and Multi species conservation strategies. Endangered species management	2
31.	Restoration and species recovery planning. Community biodiversity management	1
32.	Strategic species concepts (Keystone species, Indicator species, Umbrella and flagship species)	1
33.	Concept of sustainable development	1
	Total	47

I. Course Title : Tree Physiology and Forest Productivity

II. Course Code : FBT 607

III. Credit Hours : 2+1

IV. Aim of the course

To make the students understand the physiological factors responsible for the tree growth and how CO_2 fixation and consumption lead to growth.

V. Theory

Unit I

Introduction, tree forms in relation to environmental factors mechanism responsible for differences in tree forms stand structure and micro-climate.

Unit II

Carbon fixation by tree canopies, leaf area, interception of solar radiation and tree growth. Leaf area index and dry matter production. Radiation attenuation through canopies strategies for maximising solar energy utilization, stomatal conductance.

Unit III

Carbon consumption and export, carbon balance in trees, canopy photosynthesis. Transport and partitioning. Factors influencing net photosynthesis in trees. Relationship between the CO_2 compensation point and carbon fixation efficiency in trees. Physiology of formation of early and late woods. Resource sharing in mixed agroforestry system.

Unit IV

Evapo-transpiration factors affecting evapo-transpiration. Potential evapo-transpiration. Moisture stress, osmotic adjustment stomatal response to moisture stress. Water use efficiency drought tolerance.

Unit V

Biochemical and molecular aspects, water logging, physiology of resistance to water logging. Salt and ion stress.

Unit VI

Avoidance and tolerance mechanisms. Temperature stress, low temperature stress,physiology of resistance to frost. Heat stress, heat injury, heat avoidance and tolerance mechanism, Radiation stress, mechanism of shade tolerance, Physiological basis of pollution stress, Ozone injury Acid rain, Heavy metals.

VI. Practical

- Chlorophyll stability index;
- Leaf water potential by pressure bomb technique – porometry steady state porometer;
- Leaf temperature, transpiration rate;
- Stomatal resistance and conductance;
- Seed germination test for drought, tolerance and pre-treatment of seeds for drought tolerance;
- Water use efficiency;
- Measurement of photosynthesis.

VII. Suggested Reading

Kozlowski TT. 1971. *Growth and Development of Trees. Vol. I.* Academic Press.

Kramer PJ and Kozlowshi TT. 1979. *Physiology of Woody Plants*.Academic Press.

Ksenzhek OS and Volkov AG. 1998. *Plant Energetics*. Academic Press, New York.

Lack AJ and Evans DE. 2001. *Plant Biology- Instant Notes*. Vina Books Pvt. Ltd., New Delhi.

Larcher W. 2003. *Physiological Plant Ecology*. 4th edn, Springer-Verlag, Germany.

Luttge U. 2008. *Physiological Ecology of Tropical Plants*. Springer-Verlag, Germany Mandal AK and Gibson GL. 1997. *Forest Genetics and Tree Breeding*. CBS.

Raghavendra AS. 1991. *Physiology of Trees*. John Wiley & Sons.

Taiz L and Zeiger E. 2007. *Plant Physiology* 4t h Ed. Sinauer Associates Inc. Publishers, Sunderland.

Zimmerman RH. 1972. *Juvenility and Flowering in Woody Plants: A Review*. Hort. Science 7(5): 447-455.

Zimmermann MH and Brown CL. 1971. *Trees Structure and Function*. Springer Verlag.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1	Introduction, tree forms in relation to environmental factors mechanism responsible for differences in tree forms stand structure and micro-climate	2
2	Carbon fixation by tree canopies, leaf area, interception of solar radiation and tree growth	2
3.	Leaf area index and dry matter production. Radiation attenuation through canopies, strategies for maximising solar energy utilisation stomatal conductance	4
4.	Carbon consumption and export carbon balance in trees	2
5.	Canopy photosynthesis. Transport and partitioning. Factors influencing net photosynthesis in trees. Relationship between the CO_2 compensation point and carbon fixation efficiency in trees	2
6.	Physiology of formation of early and late woods-Resource sharing in mixed agroforestry system	3
7.	Evapo-transpiration factors affecting evapo-transpiration	2
8.	Potential evapo-transpiration. Moisture stress, osmotic adjustment	2
9.	Stomatal response to moisture stress, water use efficiency, drought tolerance	2
10.	Biochemical and molecular aspects water logging physiology of resistance to water logging	2
11.	Salt and ion stress	2
12.	Avoidance and tolerance mechanisms – temperature stress – low temperature stress physiology of resistance to frost. Heat stress – heat injury, heat avoidance and tolerance mechanism	3
13.	Radiation stress mechanism of shade tolerance	2
14.	Physiological basis of pollution stress, Ozone injury Acid rain. Heavy metals	2
	Total	32
	Practical	
1.	Chlorophyll stability index	2
2.	Leaf water potential by pressure bomb technique	2
3.	Porometry, steady state porometer leaf temperature transpiration rate stomatal resistance and conductance	2
4.	Seed germination test for drought tolerance and pre-treatment of seeds for drought tolerance	3
5.	Water use efficiency	3
6.	Measurement of photosynthesis	4
	Total	16

I. Course Title : Tree Seed Management

II. Course Code : FBT 608

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding among students in the concept of seed maturity, dormancy, stratification, seed storage and forest seed management.

V. Theory

Unit I

Concepts, classification, seed fortification, use of adjuvants, diluents, stickers, encapsulation materials, dyes, chemicals, pesticides, fungicides, animal repellents, biological materials, antibiotic and growth regulators, biofertilizers, minerals salts, bioactive substances.

Unit II

Seed infusion and involvement in synergistic factors dormancy and stratification, Physical treatment with abrasives, hot and cold temperature, radio, frequency waves, UV rays, X-rays and gamma rays.

Unit III

Methods of application and their effects on germination, seed hardening, osmotic priming in relation to stress management.

Unit IV

Seed pelleting, use of bio-fertilizers, mineral salts, growth regulators, hydrophilic substances, seed-coat polymers in stress management, sequences in seed inoculation.

Unit V

Planting value determination and storage potential evaluation, aerial seeding and its implication, use of IDS for separation of viable seed from non viable seeds mid-storage correction treatment.

VI. Practical

- Influence of seed fortification with different treatments on germination and vigour of seeds;
- Studies on seed infusion effects on germination. Vigour and planting value;
- Use of physical treatment of seeds on seed germination and vigour. Seed hardening treatments and their influence on the planting value of seeds;
- Studies on osmotic priming on stress tolerance of seedlings. Seed pelleting studies in tree seeds. Evaluation of pelletted seeds for survival percentage both in laboratory and field. Determination of storage potential of pelleted seeds;
- Use of organic solvents for seed infusion and their influence on the seed quality. Standardization of IDS method to separate viable seeds from non-viable seeds in tree species. Evaluation of effectiveness of separation by IDS method by germination test, cutting test radiographic analysis. Studies on the evaluation of mid-storage correction treatments on the viability and vigour of seeds in storage by accelerated aging test.

VII. Suggested Reading

Dutta M and Saini GC. 2009.*Advances in Forestry Research in India*, Vol. XXX. *Forest Tree Improvement and Seed Technology*. International Book Distributors.

Khullar P, Thapliyal RC, Beniwal BS, Vakshasya and Sharma A. 1991. *Forest Seeds. ICFRE.*

Lars H Schmidt. 2000. *Guide to Handling of Tropical and Subtropical Forest Seed*s. Danida Forest Seed Centre.

Mema NP. 1989. *Principles of Seed Certification and Testing*. Allied Publ.

Negi SS. 2008. *Forest Tree Seeds*. International Book Distributers.

Ram Prasad and Kandya R K. 1992. *Handling of Forestry Seeds in India.*Associated Publ.

Vanangamudi K. 2007. *Advances in Seed Science and Technology*, Volume IV. Agrobios (India).

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Concepts, classification, seed fortification, use of adjuvants, diluents, stickers, encapsulation materials, dyes, chemicals, pesticides, fungicides, animal repellents, biological materials, antibiotic and growth regulators, biofertilizers, minerals salts, bioactive substances	3
2.	Seed infusion and involvement in synergistic factors, dormancy and stratification	3
3.	Physical treatment with abrasives, hot and cold temperature, radio – frequency waves, UV rays, X-rays and gamma rays	4
4.	Methods of application and their effects on germination, seed hardening, osmotic priming in relation to stress management	3
5.	Seed pelleting, use of bio-fertilizers, mineral salts, growth regulators, hydrophilic substances, seed-coat polymers in stress management, sequences in seed inoculation	3
6.	Planting value determination and storage potential evaluation	1
7.	Aerial seeding and its implication	1
8.	Use of IDS for separation of viable seed from non viable seeds mid-storage correction treatment	2
	Total	20
	Practical	
1.	Influence of seed fortification with different treatments on germination and vigour of seeds	3
2.	Studies on seed infusion effects on germination.Vigour and planting value	3
3.	Use of physical treatment of seeds on seed germination and vigour. Seed hardening treatments and their influence on the planting value of seeds	3
4.	Studies on osmotic priming on stress tolerance of seedlings. Seed pelleting studies in tree seeds. Evaluation of pelletted seeds for survival percentage both in laboratory and field. Determination of storage potential of pelleted seeds	4
5.	Use of organic solvents for seed infusion and their influence on the seed quality. Standardization of IDS method to separate viable seeds from non-viable seeds in tree species. Evaluation of effectiveness of separation by IDS method by germination test, cutting test radiographic analysis. Studies on the evaluation of mid-storage correction treatments on the viability and vigour of seeds in storage by accelerated aging test	4
	Total	17

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Forestry
– Forest Products and Utilization

Course Title with Credit Load
M.Sc. (Forestry) in Forest Products and Utilization

Course Code		Course Title	Credit Hours
		Major Courses	
FPU 501*	I	Non Wood Forest Products Management	2+1
FPU 502	II	Applied Wood Technology	2+1
FPU 503	I	Pulp and Paper Technology	2+1
FPU 504	II	Composite Wood Technology	2+1
FPU 505*	I	Forest Products Laboratory Techniques	0+2
FPU 506*	II	Agro-techniques of Medicinal and Aromatic Crops	2+1
FPU 507	I	Breeding Techniques and Improvement of Medicinal and Aromatic Crops	2+1
FPU 508	II	Chemistry and Processing of Medicinal and Aromatic Plants	2+1
FPU 509*	I	Wood Identification	0+2
FPU 510*	II	Chemistry of Forest Products and Industries	2+1
FPU 511	I	Wood Chemistry	1+1
FPU 512	II	Wood Physics	1+1
FPU 513	I	Wood Seasoning and Preservation	2+1
FPU 514	II	Production of Medicinal and Aromatic Crops	1+1
FPU 515	I	Medicinal and Aromatic Plants in Health Care Systems	2 +0
FPU 516	II	Pharmacognosy of Medicinal and Aromatic Plants	1+1
		Minor Courses	
		Courses from Silviculture and Agroforestry or Forest Biology and Tree Improveemnt	08
		Supporting Courses	
FOR 511*	I	General Statistical Methods and Computer Applications	2+1
		Any other course relavent to MSc research problem	03
		Common Courses	
		Library and Information Services	1+0
		Technical Writing and Communications Skills	1+0
		Intellectual Property and its management in Agriculture	1+0
		Basic Concepts in Laboratory Techniques	1+0
		Agricultural Research, Research Ethics and Rural Development Programmes	1+0
FPU 591*	I/ II	Master's Seminar	1+0
	ii)	Thesis Research	
FPU 599		Master's Research	0+30

*Compulsory Core Courses

Course Contents
M.Sc. (Forestry) in Forest Products and Utilization

I. Course Title : Non Wood Forest Products Management

II. Course Code : FPU 501

III. Credit Hours : 2+1

IV. Aim of the course

To make students to understand and learn about the different non wood Forest Products and their scientific extraction, processing and disposal.

V. Theory

UNIT I

Classification of non wood forest products like gums and resins, katha, dyes, tannins, oils, raw drugs, bamboos, canes and other products.

UNIT II

Technologies for extraction of gums, resins, katha, dyes, tannins, oils, raw drugs and other products.

UNIT III

Utilization of various non wood forest products and their scientific management for processing, value addition, marketing and disposal.

UNIT IV

Quality assessment of important products and their methods for storage. Important industries based on non wood forest products and their management.

VI. Practical

- Extraction of resins, gums, katha, dyes, tannins, oils raw drugs, bamboos, canes and other products;
- Value addition techniques for these products;
- Visit to non wood forest products based industries.

VII. Suggested Reading

Linskens HF and Jackson JF. 1991. *Essential Oils and Waxes* (Ed.). Springer-Verlag Berlin Heidelberg.

Mathe A. 2015. *Medicinal and Aromatic Plants of the World-Scientific, Production, Commercial and Utilization Aspects.* Springer Netherlands.

Panda H. 2005. *Hand Book on Specialty Gums, Adhesive, Oils, Rosin And Derivatives, Resins, Oleoresins, Katha, Chemicals with others Natural Products.* Asia Pacific business press. Inc.

Panshin AJ, Harrer ES and Bethel JS. *Forest Products, their Sources, Production and Utilization.*

Shackleton S, Shackleton C and Shanley P. 2011. *Non-Timber Forest Products in the Global Context* (Ed.). Springer, Verlag Berlin Heidelberg.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Classification of non wood forest products like; gums and resins, katha, dyes, tannins, oils, raw drugs and other products	9
2.	Technologies for extraction of gums, resins, katha, dyes, tannins, oils, raw drugs and other products	8
3.	Utilization of various non wood forest products and their scientific management for processing, value addition and disposal	6
4.	Quality assessment of important products and their methods for storage	6
5.	Important industries based on non wood forest products and their management	3
	Total	32
	Practical	
1.	Extraction of resins, gums, katha, dyes, tannins, oils, raw drugs and other products	8
2.	Value addition techniques resins, gums, katha, dyes, tannins, oils, raw drugs and other products	5
3.	Visit to non wood forest products based industries	3
	Total	16

I. Course Title : Applied Wood Technology

II. Course Code : FPU 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with various aspects of wood technology and their role in different applications.

V. Theory

UNIT I

Physical properties of wood-wood density, specific gravity and methods of their determination. Effect of growth on density of wood. Moisture content and its measurement. Effect of sound on wood resonance. Color of wood, phosphorescence, fluorescence and residual luminescence. Thermal properties-conductivity and diffusivity. Electrical properties-conductivity, dielectric constant and current resistivity. Wood permeability.

UNIT II

Mechanical properties-elastic constants, plasticity, Hook's Law, Poisson's ratio, elastic constants, modulus of elasticity, factors affecting strength properties, elastic theory of bending, shear stresses in simple beams, supported beams and cantilevers carrying concentrated and uniformly distributed loads, direct and bending safe working stresses and their evaluation.

UNIT III

Standard tests of timber specimen's-compression, tensile strength. Mechanics and Rheology of wood, abrasion, brittleness and hardness. Suitability coefficient and indices of different wood species. Vibration properties.

UNIT IV

Effect of environment on mechanical properties of wood. Effect of radiations on strength of wood.

VI. Practical

- Determination of density, specific gravity, strength, hardness, modulus of elasticity, mechanical properties, thermal conductivity, electrical resistivity and dielectric constant of important domestic and imported timber species.

VII. Suggested Reading

Bodig J and Benjamin AJ. 1993. *Mechanics of Woods and Woods Composites*. Krieger Publish Company.

Brown HP. 1925. *An Elementary Manual on Indian Wood technology*. Central Publication Branch, Government of India, Calcutta.

Brown HP. 1985. *Manual of Indian Wood Technology*. International Books and Periodicals Supply Service, New Delhi.

Hill CAS. 2006. *Wood Modification: Chemical, Thermal and other Processes*. John Wiley and Sons Ltd.

Hoadley B. 2000. *Understanding Wood: A Craftsman's Guide to Wood Technology*. Taunton Press. Newtown, USA.

Kollmann FFP and Cote WAJ. 1968. *Principle of Wood Science and Technology*. Vol I, Solid wood. George Allen and Unwin Ltd London, Springer-Verlag, Berlin, Heidelberg, New York.

Panshin AJ and De ZC. 1980. *Textbook of Wood Technology*, 4th Ed. McGraw-Hill. New York.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Physical properties of wood-wood density, specific gravity and methods of determination	4
2.	Effect of growth on density of wood. Moisture content and its measurement. Effect of sound on wood resonance. Phosphorescence, fluorescence and residual luminescence	4
3.	Thermal properties-conductivity and diffusivity	2
4.	Electrical properties-conductivity, dielectric constant and current resistivity. Wood permeability	3
5.	Mechanical properties-elastic constants, plasticity, Hook's Law, Poisson's ratio, elastic constants, modulus of elasticity, factors affecting strength properties, elastic theory of bending, shear stresses in simple beams, supported beams and cantilevers carrying concentrated and uniformly distributed leads, direct and bending safe working stresses in simple and their evaluation	8
6.	Standard tests of timber specimen's-compression, tensile strength, Mechanics and Rheology of wood, abrasion, brittleness and hardness.	5
7.	Suitability coefficient and indices of different wood species. Vibration properties	3
8.	Effect of environment on mechanical properties of wood. Effect of radiations on strength of wood	3
	Total	32

Sr. No.	Topic	No. of Practical(s)
	Practical	
1.	Determination of density, strength, hardness modulus of elasticity of wood and mechanical properties of important domestic and imported timber species	9
2.	Determination electrical resistivity and dielectric constant of important domestic and imported timber species	7
	Total	16

I. Course Title : Pulp and Paper Technology

II. Course Code : FPU 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint the students with the resources and processes for making pulp and paper.

V. Theory

UNIT I

Raw material used in pulp and paper industries, characteristics and handling.

UNIT II

Pulping process, mechanical, chemical, semi-chemical and biopulping. Pulp bleaching, pulp treatment, defibering, de-knotting, brown stock washing, screening, cleaning, thickening, etc.

UNIT III

Recycled fibers, supplementary pulp treatment and additives. Paper making, paper drying, reeling, external sizing, coating, calendaring, etc.

UNIT IV

Structure of paper, its characterization and measuring strength method, optional and structural properties of paper, Type of paper: coated paper, corrugated containers, printing quality of paper, ageing of paper. Rayon industry.

VI. Practical

- Visit to pulp and paper industry;
- Study of raw materials, techniques and pulp yield, making of paper and its quality determination.

VII. Suggested Reading

Asuncion J. 2003. *The Complete Book of Paper Making*. Lark books, New York.

Bajpai P. 2018. *Biermann's Handbook of Pulp and Paper*. Vol. 1st:Raw material and pulp making. Elsevier Science, UK.

Biermann C. 1996. *Handbook of Pulping and Paper Making*. 2nd Ed. Academic Press San Diego, New York, Boston, London, Sydney, Tokyo, Toronito.

Britt KW. 1970. *Handbook of Pulp and Paper Technology*. 2nd Ed. Van Nostrand Reinhold Company, New York.

Lavigne JR. 1979. *Instrumentation Applications for the Pulp and Paper Industry*. Miller Freeman Publications.

Rao KP. 2007. *Pulp and Paper Technology: Technology, Testing and Applications*. CBS Publishing and Distributors, New Delhi.

Sjostrom E and Alen R (Eds). 1999. *Analytical Methods in Wood Chemistry Pulping and Paper Making*. Springer Series in Wood Science.

Viikari L and Lantto R. 2002. *Progress in Biotechnology*. Vol. 21st. Biotechnology in the pulp and paper industry. 1st Ed. ICBPPI. Elsevier Science.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Raw materials used in pulp and paper industries, characteristics and handling	6
2.	Pulping process, mechanical, chemical, semi-chemical and biopulping. Pulp bleaching, pulp treatment, defibering, de-knotting, brown stock washing, screening, cleaning, thickening, etc.	8
3.	Recycled fibers, supplementary pulp treatment and additives. Paper making, paper drying, reeling, external sizing, coating, calendaring, etc. Structure of paper, its characterization and measuring strength method	10
4.	Optional and structural properties of paper, Type of paper: coated paper, corrugated containers, printing quality of paper, ageing of paper	6
5.	Rayon industry	2
	Total	32
	Practical	
1.	Visit to pulp and paper industry	6
2.	Study of raw materials, techniques and pulp yield, making of paper and its quality determination	10
	Total	16

I. Course Title : Composite Wood Technology

II. Course Code : FPU 504

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge regarding the scope and processes for developing composite and modified woods.

V. Theory

UNIT I

Introduction to wood modification, its need and scope.Chemical modification of wood (acetylation, reaction with isocyanates, acetates, ethers, epoxides, etc.) Wood impregnation and compregnation, heat stabilization, wood densification.

UNIT II

Modern trends in composite wood. Wood adhesives – types, characteristics and application.

UNIT III

Plywood, laminated wood and inorganic wood composites- their manufacture, characteristics and application.

VI. Practical

- Use of different adhesives in plywood;
- Study of composite boards, study of anti-shrink efficiency of wood treated with different chemicals;
- Impregnation and compregnation of wood with chemicals.

VII. Suggested Reading

Ansell MP. 2015.*Wood Composites*. Elsevier, Science and Technology.

Hill CAS. 2006. *Wood Modification: Chemical, Thermal and Other Processes*. John Wiley and Sons Ltd.

Pizzi A and Mittal KL. 2011. *Wood Adhesives*. CRC Press, New York.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press, New York.

USDA (U.S. Department of Agriculture). 1999. *Wood Handbook: Wood as an Engineered Material*. US Department of Agriculture, Forest Service. Forest Products Laboratory, Madison, WI.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction to wood modification, its need and scope	4
2.	Chemical modification of wood (acetylation, reaction with isocyanates, acetates, ethers, epoxides, etc.)	6
3.	Wood impregnation and compregnation, heat stabilization, wood densification	6
4.	Modern trends in composite wood	4
5.	Wood adhesives – types, characteristics and application	4
6.	Plywood, laminated wood and inorganic wood composites- their manufacture, characteristics and application	8
	Total	32
	Practical	
1.	Use of different adhesives in plywood	4
2.	Study of composite boards, study of anti-shrink efficiency of wood treated with different chemicals	6
3.	Impregnation and compregnation of wood with chemicals	6
	Total	16

I. Course Title : Forest Products Laboratory Techniques

II. Course Code : FPU 505

III. Credit Hours : 0+2

IV. Aim of the course

To expose the students to the practical aspects of laboratory techniques employed in forest products.

V. Practical

- Wood and non-wood product sampling, drying and storage. Estimation of extraneous components of wood. Analysis of volatile compounds;
- Estimation of chemical composition of wood samples (hardwoods, softwood and other lignocellulosic material) and ash;
- Separation of components by column, paper, and thin layer chromatography. HPLC techniques;
- Determination of strength properties of paper and wood composites.

VI. Suggested Reading

Meyland BA and Butterfield BG. 1972. *Three-Dimensional Structure of Wood: A Scanning Electron Microscope Study*. Syracuse University Press.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press, New York.

Skaar C. 1988. *Wood-Water Relations*. Springer Series in Wood Science.

Snyder LR, Kirkland JJ and Glajch JL. 2012. *Practical HPLC Method Development*. 2nd Ed. John Wiley & Sons.

Lecture Schedule

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Wood and non-wood products sampling, drying and storage	4
2.	Estimation of extraneous components of wood. Analysis of volatile compounds	6
3.	Estimation of chemical composition of wood samples (hardwoods, softwood and other lignocellulosic material) and ash	10
4.	Separation of components by column, paper, and thin layer chromatography. HPLC techniques	6
5.	Determination of strength properties of paper and wood composites	6
	Total	32

I. Course Title : Agro-techniques of Medicinal and Aromatic Crops

II. Course Code : FPU 506

III. Credit Hours : 2+1

IV. Aim of the course

To equip the student with the conventional and commercial production techniques of medicinal and aromatic plant species.

V. Theory

UNIT I

Importance of medicinal and aromatic plants in human health, national economy and related industries. Need of cultivation of medicinal and aromatic plants as agricultural crops. Concept of organic farming, GACP and GAP in medicinal and aromatic crops production. Quality concern in plant based drugs.

UNIT II

Introduction and importance, climate and soil requirements, cultural practices, harvesting and yield, important constituents of medicinal plants – Mulhathi, Senna, *Gloriosa superba*, *Valeriana jatamansi, Swertia chirayita,* Isabgol, *Rauwolfia serpentina, Withania sominifera,* Opium Poppy, *Aloe vera*, Satavar, *Stevia rebaudiana,* Safed Musli, Kalmegh and other important species of the region.

UNIT III

Introduction and importance, climate and soil requirements; cultural practices; harvest and yield; important constituents of aromatic plants – Citronella, Palmarosa, Mentha, Basil, Lemon grass, Rose, *Tagetes minuta*, Lavender, Rosemary, Patchouli, Geranium and other important species of the region.

VI. Practical

- Morphological identification of listed plants and their economic parts, maturity indices;
- Preparation and layout of nursery and field, methods of seed sowing/ transplantation, cultural operations in MAP crops;
- Raising and harvesting of at least one crop grown in the region;
- Visit to government and private Pharmaceutical units/ Institutes in adjoining areas;
- Visit to large scale herb growing and processing units engaged in commercial cultivation and preparation of purified phytochemical/ standardized extracts;
- Visit to nearby marketing/ trade centres.

VII. Suggested Reading

Atul CK and Kapur BK. 1982. *Cultivation and Utilization Of Medicinal Plants*. RRL, CSIR, Jammu-Tawi.

Chadha KL and Gupta R. 2006. *Advances in Horticulture*. Vol. XI. Medicinal and aromatic plants. Malhotra Publishing House.

Chopra AK. 2007. *Medicinal Plants: Conservation, Cultivation and Utilization*. Daya Books.

Chopra RN. Nayar SL and Chopra IC. 1956. *Glossary of Indian Medicinal Plants.* CSIR, New Delhi.

EIRI Board. 2007. *Handbook of Medicinal and Aromatic Plants: Cultivation, Utilization and Extraction Processes*. Engineers India Research Institute, New Delhi.

Gunther E. 1975. *The Essential Oils*. Robert, K Krieger Pub. Co, New York.

Khan IA and Khanum A. 2005. *Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health*. 1st Ed. Ukaaz Publications.

Muralia S. 2006. *Medicinal and Aromatic Plants* 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Importance of medicinal and aromatic plants in human health, national economy and related industries. Need of cultivation of Medicinal and aromatic plants as agricultural crops	2
2.	Concept of organic farming, GACP and GAP in medicinal and aromatic crop production. Quality concern in plant based drugs	3
3.	Introduction and importance, botanical features, climate and soil requirements, cultural practices, harvesting and yield and important constituents of medicinal plants – Mulhathi, Senna, *Gloriosa superba*, *Valeriana jatamansi, Swertia chirayita,* Isabgol, *Rauwolfia serpentina, Withania somnifera,* Opium Poppy, *Aloe vera*, Satavar, *Stevia rebaudiana,* Safed Musli, Kalmegh and other important species of the region	15

Sr. No.	Topic	No. of Lecture(s)
4.	Introduction and importance, climate and soil requirements; cultural practices; harvest and yield; important constituents of aromatic plants - Citronella, Palmarosa, Mentha, Basil, Lemon grass, Rose, *Tagetes minuta*, Lavender, Rosemary, Patchouli, Geranium and other important species of the region	12
	Total	32

Practical

1.	Morphological identification of listed plants and their economic parts, maturity indices	3
2.	Preparation and layout of nursery and field, methods of seed sowing/ transplantation, cultural operations in MAP crops	4
3.	Raising and harvesting of at least one crop grown in the region	3
4.	Visit to government and private Pharmaceutical units/ Institutes in adjoining areas. Visit to large scale herb growing and processing units engaged in commercial cultivation and preparation of purified phytochemical/ standardized extracts	4
5.	Visit to nearby marketing/ trade centres	2
	Total	16

I. Course Title : Breeding Techniques and Improvement of Medicinal and Aromatic crops

II. Course Code : FPU 507

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with the breeding techniques and quality improvement of medicinal and aromatic crops.

V. V.Theory

UNIT I

Plant biodiversity, Major objectives of breeding of medicinal and aromatic crops. Plant introduction, domestication and germplasm conservation. Modes of pollination, male sterility, self incompatibility and apomixis. Production and maintenance of pure seeds of medicinal and aromatic plants.

UNIT II

Principles of plant breeding for self pollinated and cross pollinated crops. Selection, Hybridization-techniques and consequences. Hetersosis and inbreeding depression. Different plant breeding methods for self pollinated, cross pollinated and asexually propagated crops. Mutation and polyploidy breeding. Distinctiveness, uniformity, stability testing in medicinal and aromatic crops.

UNIT III

Breeding for quality parameters in medicinal and aromatic crops. Achievements and prospects in breeding of important medicinal and aromatic crops- *Rauvolfia* *serpentina, Plantago ovata, Cassia angustifolia, Ocimum* spp., *Withania somnifera, Valeriana* spp., *Opium poppy, Gloriosa superb, Andrographis paniculata, Mentha* spp., *Geranium, Cymbopogon* spp., and other important crops.

UNIT IV

Legislation in conservation of medicinal and aromatic plants- IPR issues in medicinal and aromatic plants.

VI. Practical

- Identification based on morphological features;
- Pollen viability and germination testing;
- Stigma receptivity;
- Field practice in emasculation, selfing and crossing in different medicinal and aromatic crops;
- Determination of mode of pollination and hybridization in different medicinal and aromatic crops.

VII. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture.* Vol. XI. Medicinal and aromatic plants. Malhotra Publishing House.

Gupta AK and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Gupta AK, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants*. ICMR.

Johnson CB and Franz C. 2005. *Breeding Research on Aromatic and Medicinal Plants*. International Book Distributor.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publishing.

Singh BD. 2010. *Plant Breeding- Principles and Methods*. Kalyani Publishers.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Plant biodiversity, Major objectives of breeding of medicinal and aromatic crops. Plant introduction, domestication and germplasm conservation	3
2.	Modes of pollination, male sterility, self incompatibility and apomixis. Production and maintenance of pure seeds of medicinal and aromatic plants	3
3.	Principles of plant breeding for self pollinated and cross pollinated crops	3
4.	Selection, Hybridization-techniques and consequences	2
5.	Hetersosis and inbreeding depression	3
6.	Different plant breeding methods for self pollinated, cross pollinated and asexually propagated crops	5
7.	Mutation and polyploidy breeding	2
8.	Distinctiveness, uniformity, stability testing in medicinal and aromatic crops	3
9.	Breeding for quality parameters in medicinal and aromatic crops	2
10.	Achievements and prospects in breeding of important medicinal and aromatic crops- *Rauvolfia serpentina, Plantago ovata, Cassia angustifolia, Ocimum* sp., *Withania somnifera, Valeriana* sp., *Opium poppy, Gloriosa superba, Andrographis paniculata, Mentha* sp., *Geranium, Cymbopogon* sp., and other important crops	5

Sr. No	Topic	No. of Practical(s)
11.	Legislation in conservation of medicinal and aromatic plants- IPR issues in medicinal and aromatic plants	1
	Total	32

Practical

1.	Identification based on morphological features	3
2.	Pollen viability and germination testing	3
3.	Stigma receptivity	2
4.	Field practice in emasculation	2
5.	Selfing and crossing in different medicinal and aromatic crops	4
6.	Determination of mode of pollination and hybridization in different medicinal and aromatic crops	2
	Total	16

I. Course Title : Chemistry and Processing of Medicinal and Aromatic Plants

II. Course Code : FPU 508

III. Credit Hours : 2+1

IV. Aim of the course

To understand the chemistry of phytopharmaceuticals and their processing as industrial products.

V. Theory

UNIT I

Organic compounds and their classification such as aliphatic, aromatic, alkaloids, steroids, terpenoids, glycosides, phenolic compounds, heterocyclic compounds and carbohydrates.

UNIT II

Primary and Secondary plant metabolites and theurapeutical uses of phytoconstituents such as anthraquinones, steroidal and triterpenoidal glycosides, phenolic compounds, lipids, alkaloids and terpenoids.

UNIT III

Basic principles and extraction techniques of different phytoconstituents. Analysis of active principles using TLC, HPLC, Gas chromatography, etc. Quality standards in herbal products. Drug descriptors for medicinal and aromatic plants.

UNIT IV

Postharvest processing-drying, grading and storage. Extraction techniques of essential oils and their quality analysis.

VI. Practical

- Use of thin layer and column chromatography during extraction and purification of phytopharmaceuticals;

- Preparation of active constituent enriched extracts;
- Extraction of Essential oils and their quality evaluation;
- Preparation of concretes and absolutes. Use of HPLC and GC in quality evaluation.

VII. Suggested Reading

Bedi S, Singh T and Vyas SP. 2012. *A Handbook of Aromatic and Essential Oil Plants: Cultivation, Chemistry, Processing and Uses*. Agrobios (India).

Finar IL. 2002. *Organic Chemistry*. Vol. I & II. *Pearson Education* India.

Raaman N. 2006. *Phytochemical Techniques*. New India Publishing Agency, N. Delhi.

Singh MP and Panda H. 2005. *Medicinal Herbs with their Formulations*. Vol-1st. Daya Publishing House.

Singh S. 2009. *Essentials of Pharmacology*. 2nd Ed. New Age International Publisher.

Wagner H and Bladt S. 2009. *Plant Drug Analysis- A Thin Layer Chromatography Atlas*. Springer (India) Pvt. Ltd.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Organic compounds and their classification such as aliphatic, aromatic, alkaloids, steroids, terpenoids, glycosides, phenolic compounds, heterocyclic compounds and Carbohydrates	9
2.	Primary and secondary plant metabolites	4
3.	Theurapeutical uses of phytoconstituents such as anthraquinones, steroidal and triterpenoidal glycosides, phenolic compounds, lipids, alkaloids and terpenoids	6
4.	Basic principles and extraction techniques of different . phytoconstituentsAnalysis of active principles using TLC, HPLC, Gas chromatography, etc. Quality standards in herbal products	4
5.	Drug descriptors for medicinal and aromatic plants	2
6.	Postharvest processing-drying, grading and storage	4
7.	Extraction techniques of essential oils and their quality analysis	3
	Total	32
	Practical	
1.	Use of thin layer and column chromatography during extraction and purification of phytopharmaceuticals	3
2.	Preparation of active constituent enriched extracts	3
3.	Extraction of Essential oils and their quality evaluation	2
4.	Preparation of concretes and absolutes	2
5.	Use of HPLC and GC in quality evaluation	6
	Total	16

I. Course Title : Wood Identification

II. Course Code : FPU 509

III. Credit Hours : 0+2

IV. Aim of the course

The course deals with the use of anatomical features of wood in timber identification and classification.

V. Practical

- Study of planes of wood, gross features and physical characteristics of important woods;
- Identification of different types of cells and tissues;
- Anatomical studies of soft and hard woods. Anatomical studies of reaction wood;
- Classification of timber using dichotomous key;
- Modern timber identification techniques.

VI. Suggested Reading

Agarwal VK and Upadhaya SD. 2006. *Agrotechniques of Medicinal and Aromatic Plants*. Satish Serial Publishing House.

Anoop EV. 1971. *Timber Identification Manual*. Forest Research Institute, Dehradun.

Dutta JC. 1964. *Botany for Degree Students*. Oxford University Press, Bombay-Calcutta-Madras.

Govil JN, Pandey J, Shivakumar BG and Singh VK. 2004. *Crop Improvement, Production Technology, Trade Commerce*.

Lakshman HC and Inchal RF. 2012. *Indigenous Medicinal Plants and their Practical Utility*.

Meier E. 2015. *Wood Identifying and Using Hundreds of Woods Worldwide*. Wood database.

Porter T. 2004. *Wood Identification and Use*. Guild of Master Craftsman, UK.

Purkayastha SK. 1982. *Indian Woods: Their Identification Properties and Uses*. Controller of Publication.

Rao R and Juneja KDS. 1971. *A Handbook for Field Identification of Fifty Important Timbers of India*. Manager of Publications.

Vashishta PC. 1985. *A Text Book of Botany*. S. Chand Publishing Company, New Delhi.

Lecture Schedule

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Study of planes of wood,gross features and physical characteristics of important woods	6
2.	Identification of different types of cells and tissues	5
3.	Anatomical studies of soft and hard woods. Anatomical studies of reaction wood	10
4.	Classification of timber using dichotomous keys	6
5.	Modern timber identification techniques	5
	Total	32

I. Course Title : Chemistry of Forest Products and Industries

II. Course Code : FPU 510

III. Credit Hours : 2+1

IV. Aim of the course

The course will equip the students regarding forest based industries and their impact on the economy of the country. To support the studies on the role of various products such as pulp, paper, composite wood, furniture match boxes, sports, pencil making, resins and gums, katha, tannins and various types of other non- timber and wood products either produced or processed in these industries. Practicals will make them aware regarding extraction and processing methods of different forest products.

V. Theory

UNIT I

Importance of forest based industries in relation to Indian economy. Role of Chemistry in relation to forest products.

UNIT II

Classification and description of different forest based industries – pulp and paper, composite wood, furniture, bamboo, sports goods, pencil making, match box and splint making. Use of lesser known wood species for commercial purposes.

UNIT III

Cell wall constituents. Chemistry of cellulose, starch, hemicelluloses and lignin. Extraneous components of wood – water and organic solvent soluble.

UNIT IV

Chemical composition of oleoresin from major pine species. Structural difference among different gums (arabic, ghatti, tragacanth, etc.).

UNIT V

Chemical nature and uses of volatile oils, tannins, katha and cutch and important forest based dyes and pigments.

VI. Practical

- Estimation of cell wall constituents – Hemicelluloses and lignin;
- Extraction of essential oils, resins and tannins;
- Wood pulping. Acetylation of wood;
- Visit to nearby forest based industries.

VII. Suggested Reading

Bowyer JL, Shmulsky R and Haygreen JG. 2003. *Forest Products and Wood Science: An Introduction*. 4th Ed. Blackwell Publishing.

Chung and Deborah DL. 2003. *Composite Materials-Functional Materials for Modern Technologies*. Springer,Verlag London.

David AT. 2013. *Forest Products: Advanced Technologies and Economic Analyses*. Elsevier.

Eriksson KEL, Blanchette RA and Ander P. 1990. *Microbial and Enzymatic Degradation of Wood and Wood Components*. Springer,Verlag Berlin Heidelberg.

Linskens HF and Jackson JF. 1991. *Essential Oils and Waxes* (Ed.). Springer-Verlag Berlin Heidelberg.

Panda H. 2005. *Hand Book on Specialty Gums, Adhesive, Oils, Rosin And Derivatives, Resins, Oleoresins, Katha, Chemicals with Others Natural Products*. Asia Pacific business press. Inc.

Rojas OJ. 2016. *Cellulose Chemistry and Properties: Fibers, Nanocelluloses and Advanced Materials (Ed.)*. Springer International Publishing.

Rowell RM. 2013. *Hand Book of Wood Chemistry and Wood Composites*. CRC press, Taylor and Francis group.

Shackleton S, Shackleton C and Shanley P. 2011. *Non-Timber Forest Products in the Global Context (Ed.)*. Springer, Verlag Berlin Heidelberg.

Sharma LC. 2012. *Development of Forests and Forest Based Industries*. M/s Bishen Singh Mahendra Pal Singh.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Importance of forest based industries in relation to Indian economy	1
2.	Role of chemistry in relation to forest products	1
3.	Classification and description of different forest based industries – pulp and paper and composite wood	6
4.	Classification and description of different forest based industries like; Furniture, bamboo, sports goods, pencil making, match box and splint making	5
5.	Use of lesser known wood species for commercial purposes	2
6.	Cell wall constituents. Chemistry of cellulose, starch, hemicelluloses and lignin	4
7.	Extraneous components of wood – water and organic solvent soluble	2
8.	Chemical composition of oleoresin from major pine species	3
9.	Structural difference among different gums (arabic, ghatti, tragacanth, etc.)	2
10.	Chemical nature and uses of volatile oils, tannins, katha and cutch	3
11.	Chemical nature and uses of important forest based dyes and pigments	3
	Total	**32**
	Practical	
1.	Estimation of cell wall contents – Hollocellulose and lignin	5
2.	Extraction of essential oils	2
3.	Extraction of resins and tannins	3
4.	Wood pulping	2
5.	Acetylation of wood	2
6.	Visit to nearby forest based industries	2
	Total	16

I. Course Title : Wood Chemistry

II. Course Code : FPU 511

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge about the chemical properties of wood, cell wall constituents and wood extractions.

V. Theory

UNIT I

Chemical composition of wood: Cell wall constituents- cellulose, lignin, hemicellulose, peptic substances, etc.

UNIT II

Volatile oils and extractives, cellulose derivatives and their applications.

UNIT III

Hydrolysis and fermentation of lignocellulosic materials. Pyrolysis and gasification of wood.

VI. Practical

- Extraction of cellulose, hemicellulose, lignin, extractives and ash content of wood.

VII. Suggested Reading

Coppen JJW. 1995. *Gums, Resin and Latex of Plant Origin*. Food and Agriculture Organizations, Rome.

Rowe JW. 1989. *Natural Products of Woody Plants*. Springer Series in Wood Science.

Rowell RM. 1984. *The Chemistry of Solid Wood (Advances in Chemistry Series)*. American Chemical Society.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press.

Singh A. 1967. *Plant Physiology*. Readers in Botany, Allahabad University.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Chemical composition of wood: Cell wall constituents- cellulose, lignin, hemicellulose, peptic substances, etc.	5
2.	Volatile oils and extractives, cellulose derivatives and their applications	4
3.	Hydrolysis and fermentation of lignocellulosic materials	4
4.	Pyrolysis and gasification of wood	3
	Total	16
	Practical	
1.	Extraction of cellulose	3
2.	Extraction of Hemicellulose	3
3.	Extraction of lignin	4
4.	Extraction of wood extractives	3
5.	Extraction of ash content of wood	3
Total	16	

I. Course Title : Wood Physics

II. Course Code : FPU 512

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint with the physical characteristics and strength properties of wood.

V. Theory

UNIT I

Wood density, thermal, electrical and acoustic properties of wood. Mechanics and Rheology of wood, elasticity, plasticity and creep (tensile compression and bending strength)

UNIT II

Toughness, torsion, shear, hardness and abrasion strength. Acoustic and acousto-ultrasonics based non-destructive evaluation technique.

VI. Practical

- Determination of wood density;
- Study of thermal, electrical and acoustic properties of wood;
- Determination of tensile and bending properties of wood.

VII. Suggested Reading

Brown HP. 1925. *An Elementary Manual on Indian Wood Technology*. Central Publication Branch Government of India.

Dutta AC. 1964. *Botany for Degree Students*. Oxford University Press.

Franz FP, Kollmann and Wilfred AJC. 1968. *Principle of Wood Science and Technology*. Vol I. Solid wood. George Allen and Unwin Ltd London, Springer-Verlag, Berlin, Heidelberg.

Franz FP, Kollmann, Kuwnzi E and Stamm AJ. 1975. *Principle of Wood Science and Technology*. Wood based material. Vol. II Springer-Verlag, Berlin, Heidelberg.

Meyland BA and Butterfield BG (Eds). 1972. *Three-Dimensional Structure of Wood: A Scanning Electron Microscope Study*. Syracuse University Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Wood density, thermal, electrical and acoustic properties of wood.	4
2.	Mechanics and Rheology of wood, elasticity, plasticity and creep (tensile compression and bending strength)	5
3.	Toughness, torsion, shear, hardness and abrasion strength	4
4.	Acoustic and acousto-ultrasonics based non-destructive evaluation technique	3
	Total	16
	Practical	
1.	Determination of wood density,	7
2.	Study of thermal, electrical and acoustic properties of wood	5
3.	Determination of tensile and bending properties of wood	4
	Total	16

I. Course Title : Wood Seasoning and Preservation

II. Course Code : FPU 513

III. Credit Hours : 2+1

IV. Aim of the course

To understand the importance of wood seasoning and preservation for utilizing secondary timber for multipurpose use.

V. Theory

UNIT I

Wood water relationship, absorption behaviour and wood drying, Refractory and non refractory behaviour of wood, Wood seasoning, types- air, kiln and special seasoning methods like steaming, chemical, high temperature drying, vacuum drying and water conditioning.

UNIT II

Defects of timber- natural, seasoning defects, defects due to external agencies, machining defects. Effect of defects on utilization.

UNIT III

Detection and diagnosis of discolouration and decay in wood: decaying agencies- fungi, insects, borer, etc.

UNIT IV

Wood preservation: preservatives and treatment processes. Advantages and safety concern of wood preservatives, fire retardants. Graveyard test and anti-fungal activity of wood. Bio-preservation.

VI. Practical

- Determination of moisture content and swelling coefficients of different woods;
- Comparative studies on air and kiln dried woods;
- Analysis of decayed wood for physical and chemical parameters;
- Treatment of wood with different types of preservatives. Graveyard test.

VII. Suggested Reading

FAO. 2007. *Wood Preservation Manual*. International Book Distributor.

Hunt GM. 1967. *Wood Preservation* 3rd Ed. Mc GRAW-HILL Book Company.

Pandey CN and Jain VK. 1992. *Wood Seasoning Technology*. FRI, Dehradun.

Purushotham A, Pande JN and Jadhav. 1959. *Wood Preservation In India*. Manager of Publications.

Winn W. 1919. *Timbers and their Uses*. London George Rotledge & Sons Ltd.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Wood water relationship, absorption behaviour and wood drying	4
2.	Refractory and non refractory behaviour of wood	4
3.	Wood seasoning, types- air, kiln and special seasoning methods like steaming, chemical, high temperature drying, vacuum drying and water conditioning	6
4.	Defects of timber- natural, seasoning defects, defects due to external agencies, machining defects	4
5.	Effect of defects on utilization	2
6.	Detection and diagnosis of discolouration and decay in wood: decaying agencies- fungi, insects, borer, etc.	4
7.	Wood preservation: preservatives and treatment processes	2
8.	Advantages and safety concern of wood preservatives, fire retardants	2
9	Graveyard test and anti-fungal activity of wood. Bio-preservation	4
	Total	32

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Determination of moisture content and swelling coefficients of different woods	3
2.	Comparative studies on air and kiln dried woods	3
3.	Analysis of decayed wood for physical and chemical parameters	4
4.	Treatment of wood with different types of preservatives. Graveyard test	6
	Total	16

I. Course Title : Production of Medicinal and Aromatic Crops

II. Course Code : FPU 514

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint the students with the plant production techniques.

V. Theory

UNIT I

Modes of reproduction in MAP crops and their relevance in maintaining genetic purity of crops. Concept of quality seed production and maintenance.

UNIT II

Soil fertility, essential nutrient elements- functions, deficiency symptoms, availability and factors affecting their availability. Soil micro-organisms and their role in organic matter decomposition. Importance of pH and C:N ratio in plant nutrition. Concept of bio-fertlizers and their potential for use in medicinal and aromatic crops.

UNIT III

Essentials of nursery production, criteria of site selection, and types of nursery, establishment of a model nursery. Nursery raising of medicinal plants. Tissue culture technique and *in-vitro* propagation of important MAPs.

UNIT IV

Plant protection measures in medicinal and aromatic crops, Quality parameters of seedlings and nursery stock.

VI. Practical

- Asexual/ vegetative reproduction techniques- cutting, budding, layering, etc.;
- Methods of seed collection and storage techniques;
- *In-vitro* propagation techniques;
- Determination of pH, organic matter and N,P,K from soil.

VII. Suggested Reading

Atul CK and Kapur BK. 1982. *Cultivation and Utilization of Medicinal Plants.* RRL, CSIR, Jammu-Tawi.

Chopra AK. 2007. *Medicinal Plants: Conservation, Cultivation and Utilization*. Daya Books.

Chopra RN. Nayar SL and Chopra IC. 1956. *Glossary of Indian Medicinal Plants*. CSIR, New Delhi.

EIRI Board. 2007. *Handbook of Medicinal and Aromatic Plants: Cultivation, Utilization and Extraction Processes*. Engineers India Research Institute, New Delhi.
Gunther E. 1975. *The Essential Oils*. Robert, K Krieger Pub. Co, New York.
Khan IA and Khanum A. 2005. *Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health*. 1st Ed. Ukaaz Publications.
Muralia S. 2006. *Medicinal and Aromatic Plants* 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Modes of reproduction in crop plants and their relevance in maintaining genetic purity of crops. Concept of quality seed production and maintenance	2
2.	Soil fertility, essential nutrient elements- functions, deficiency symptoms, availability and factors affecting their availability. Soil micro-organisms and their role in organic matter decomposition. Importance of pH and C:N ratio in plant nutrition. Concept of bio-fertlizers and their potential for use in medicinal and aromatic crops	5
3.	Essentials of nursery production, criteria of site selection, and types of nursery, establishment of a model nursery. Nursery raising of medicinal plants. Mode of plant propagation techniques. Tissue culture technique and *in-vitro* propagation of important MAPs	6
4.	Plant protection measures in medicinal and aromatic crops, Quality parameters of seedlings and nursery stock	3
	Total	16
	Practical	
1.	Asexual/ vegetative reproduction techniques-cutting, budding, layering, etc.	5
2.	Methods of seed collection and storage techniques	2
3.	*In-vitro*-propagation techniques	3
4.	Determination of pH, Organic matter and N,P,K from soil	6
	Total	16

I. Course Title : Medicinal and Aromatic Plants in Health Care Systems

II. Course Code : FPU 515

III. Credit Hours : 2 + 0

IV. Aim of the course

To acquaint the student with the importance of plants used in modern and AYUSH methods of treatment.

V. Theory

UNIT I

Concept of Health Care systems

UNIT II

Brief introduction to Ayurveda, Unani, Sidha, Homeopathy, Allopathy, Naturopathy, Electrohomoeopathy, etc.

UNIT III

Important medicinal plants used in treating various diseases in modern and complementary systems.

UNIT IV

Biological activity of selected medicinal plants. Methods of preparing poultices, decoctions, powders, tinctures, active content rich extracts.

VI. Suggested Reading

Atul CK and Kapur BK. 1982. *Cultivation and Utilization of Medicinal Plants*. RRL, CSIR, Jammu-Tawi.

Chopra AK. 2007. M*edicinal Plants: Conservation, Cultivation and Utilization*. Daya Books.

Chopra RN. Nayar SL and Chopra IC. 1956. *Glossary of Indian Medicinal Plants*. CSIR, New Delhi.

Cunningham A. 2014. *Applied Ethnobotany: "People, Wild Plant Use and Conservation*". Taylor & Francis.

Gunther E. 1975. *The Essential Oils*. Robert, K Krieger Pub. Co, New York.

Jain SK. 1968. *Medicinal Plants*. National book trust, New Delhi. Oxford & IBH, New Delhi.

Khan IA and Khanum A. 2005. *Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health*. 1st Ed. Ukaaz Publications.

Maheshwari JK. 2000. *Ethnobotany and Medicinal Plants of Indian Subcontinent*. Scientific Publishers,Jodhpur, India.

Muralia S. 2006. *Medicinal and Aromatic Plants* 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Concept of Health Care systems	2
2.	Brief introduction to Ayurveda, Unani, Sidha, Homeopathy, Allopathy, Naturopathy, Electrohomoeopathy, etc.	10
3.	Important medicinal plants used in treating various diseases in modern and complementary systems.	6
4.	Biological activity of selected medicinal plants.	6
5.	Methods of preparing poultices, decoctions, powders, tinctures, active content rich extracts	8
	Total	32

I. Course Title : Pharmacognosy of Medicinal and Aromatic Plants

II. Course Code : FPU 516

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding about microscopical, macroscopical and chemical methods of drug identification.

V. Theory

UNIT I

History and scope of pharmacognosy, Pharmaceutical products. Classification of natural drugs. Chemical nature of drugs. Pharmacognostic analysis of drug plants based on botanical, chemical and histological features.

UNIT II

Evaluation based on pharmacopoeial standards for both single drugs and compound formulations most commonly used in different systems of medicines.

UNIT III

Pharmacognostic features of Sarpagandha, Jatamansi, Ashwagandha, Turmeric, Punarnava, *Ephedra, Gymnema*, Senna, Amla, Gokhru, Isabgol, Black pepper, Banafsha, Arjun or any other commercially species specific to the region.

VI. Practical

- Identification of drugs by morphological characters;
- Physical and chemical tests for evaluation of drugs;
- Gross anatomical studies of Ginger, Ashwagandha, Senna, *Gentiana*, Kalmegh, Sarpagandha, Mulhathi, *Aconitum* species or any other important species relevant to the region.

VII. Suggested Reading

Atul CK and Kapur BK. 1982. *Cultivation and Utilization of Medicinal Plants*.RRL, CSIR, Jammu-Tawi.

Chopra AK. 2007. *Medicinal Plants: Conservation, Cultivation and Utilization*. Daya Books.

Chopra RN, Nayar SL and Chopra IC. 1956. *Glossary of Indian Medicinal Plants*. CSIR, New Delhi.

Cunningham A. 2014. *Applied Ethnobotany: "People, Wild Plant Use and Conservation*". Taylor & Francis.

Cupp J and Tracy TS. 2003. *Dietary Supplements: Toxicology and Clinical Pharmacology*. Humana Press.

Gunther E. 1975. *The Essential Oils*. Robert, K Krieger Pub. Co, New York.

Gupta K, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants*.

Jain SK. 1968. *Medicinal Plants*. National book trust, New Delhi. Oxford & IBH, New Delhi.

Khan IA and Khanum A. 2005. *Medicinal and Aromatic Plants of India; Herbal Wealth for Human Health*. 1st Ed. Ukaaz Publications.

Maheshwari JK. 2000. *Ethnobotany and Medicinal Plants of Indian Subcontinent*. Scientific Publishers,Jodhpur, India.

Muralia S. 2006. *Medicinal and Aromatic Plants*. 1st Ed. Neha Publishers and Distributors.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	History and scope of pharmacognosy	1
2.	Pharmaceutical products. Classification of natural drugs. Chemical nature of drugs	3
3.	Pharmacognostic analysis of drug plants based on botanical, chemical and histological features	4
4.	Evaluation based on pharmacopoeial standards for both single drugs and compound formulations most commonly used in different systems of medicines	3
5.	Pharmacognostic features of Sarpagandha, Jatamansi, Ashwagandha, Turmeric, Punarnava, Ephedra, Gymnema, Senna, Amla, Gokhru, Isabgol, Black pepper, Banafsha, Arjun or any other commercially species specific to the region	5
	Total	16

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Identification of drugs by morphological characters	3
2.	Physical and chemical tests for evaluation of drugs	6
3.	Gross anatomical studies of Ginger, Ashwagandha, Senna, Gentiana, Kalmegh, Sarpagandha, Mulhathi, *Aconitum* species or any other important species relevant to the region	7
	Total	16

Course Title with Credit Load
Ph.D. (Forestry) in Forest Products and Utilization

Course Code		Course Title	Credit Hours
		Major Courses	
FPU 601*	I	Developments in Wood and Non-Wood Forest Products	3+0
FPU 602	II	Energy and Chemicals from Wood	2+0
FPU 603	I	Wood and Wood Technology	2+1
FPU 604*	II	Analytical Techniques in Forest Products	1+2
FPU 605	I	Chemistry of Medicinal and Aromatic Plants	2+1
FPU 606	II	Processing Technology of Forest Products	2+1
FPU 607	I	Value Addition and Marketing of Forest Products	2+1
FPU 608	II	Modern Trends in Wood Modification	2+1
FPU 609	I	Development in Pulp and Paper Technology	2+0
FPU 610	II	Application of Traditional Knowledge	2+0
FPU 611	I	Production of Quality Planting Material of Medicinal and Aromatic Plants	2+1
FPU 612	II	Processing Technology of Medicinal and Aromatic Plants	2+1
FPU 613	I	Biosynthesis of Secondary Metabolites	3+0
FPU 614	II	Value Additions and Marketing of Medicinal and Aromatic Plants	2+1
		Minor Courses	
		Courses from Silviculture and Agroforestry or Forest Biology and Tree Improvement	06
		Supporting Courses	
FOR 610*	I	Research Methodology in Forestry	2+1
FOR 611	II	Research and Publication Ethics	1+1
FPU 691*	I/ II	Doctoral Seminar	1+0
FPU 692*	I/ II	Doctoral Seminar	1+0
		ii) Thesis Research	
FPU 699		Doctoral Research	0+75

*Compulsory Core Courses

Course Contents
Ph.D. (Forestry) in Forest Products and Utilization

I. Course Title : Developments in Wood and Non-wood Forest Products

II. Course Code : FPU 601

III. Credit Hours : 3+0

IV. Aim of the course

To acquaint the students regarding updated and advance technology of timber mechanics, wood derivatives, export and import potential of non timber forest produce and computer applications in various forest products.

V. Theory

UNIT I

Mechanics of wood and wood composites, Application of orthotropic and non-linear constitutive relations, Laminate theory and failure criterion in the prediction of mechanical properties of solid woods; Wood-polymer; Hybrid composite processing.

UNIT II

Principles of industrial wood processes, products derived from wood by chemical processes and value added wood products, properties of construction, Wood polymers and surface chemistry, fundamentals of adhesion and fracture in adhesively bonded wood, adhesive systems used for wood with emphasis in wood based composites.

UNIT III

Methods of extraction, chemistry, processing, import and export potential of gums, resins, tannins, dyes, essential oils, fixed oils, cutch and katha, drugs, spices, poisons, insecticides, pesticides, wild edible fruits, etc.

UNIT IV

Computer application system in forest products, Use of information technologies to integrate material, quality and market fluctuations.

VI. Suggested Reading

Arnason JT, Rachel M and Romeo JT. 1995. *Phytochemistry of Medicinal Plants*. Springer, US.

Bowyer JL, Shmulsky R and Haygreen JG. 2003. *Forest Products and Wood Science: An Introduction. 4th Ed.* Blackwell Publishing.

Chung and Deborah DL. 2003. *Composite Materials-Functional Materials for Modern Technologies*. Springer,Verlag London.

David AT. 2013. *Forest Products: Advanced Technologies and Economic Analyses*. Elsevier.

Linskens HF and Jackson JF. 1991. *Essential Oils and Waxes (Ed.)*. Springer-Verlag Berlin Heidelberg.

Mathe A. 2015. *Medicinal and Aromatic Plants of the World-Scientific, Production, Commercial and Utilization Aspects*. Springer Netherlands.

Panda H. 2005. *Hand Book on Specialty Gums, Adhesive, Oils, Rosin and Derivatives, Resins, Oleoresins, Katha, Chemicals with others Natural Products*. Asia Pacific business press. Inc.

Rojas OJ. 2016. *Cellulose Chemistry and Properties: Fibers, Nanocelluloses And Advanced Materials (Ed.)*. Springer International Publishing.

Rowell RM. *Hand Book of Wood Chemistry and Wood Composites*. 2013. CRC press, Taylor and Francis group.

Shackleton S, Shackleton C and Shanley P. 2011. *Non-Timber Forest Products in the Global Context (Ed.)*. Springer, Verlag Berlin Heidelberg.

Sharma LC. 2012. *Development of Forests and Forest Based Industries*. M/s Bishen Singh Mahendra Pal Singh.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Mechanics of wood and wood composites	4
2.	Application of orthotropic and non-linear constitutive relations	2
3.	Laminate theory and failure criterion in the prediction of mechanical properties of solid woods	3
4.	Wood-polymer; Hybrid composite processing	4
5.	Principles of industrial wood processes, products derived from wood by chemical processes and value added wood products, properties of construction	6
6.	Wood polymers and surface chemistry	4
7.	Fundamentals of adhesion and fracture in adhesively bonded wood, adhesive systems used for wood with emphasis in wood based composites	3
8.	Methods of extraction, chemistry and processing of gums, resins, tannins, dyes, essential oils, fixed oils, cutch and katha, drugs, spices, poisons, insecticides, pesticides, wild edible fruits, etc.	8
9.	Import and export potential of gums, resins, tannins, dyes, essential oils, fixed oils, cutch and katha, drugs, spices, poisons, insecticides, pesticides, wild edible fruits, etc.	7
10.	Computer application system in forest products	2
11.	Use of information technologies to integrate material, quality and market fluctuations	2
	Total	45

I. Course Title : Energy and Chemicals from Wood

II. Course Code : FPU 602

III. Credit Hours : 2+0

IV. Aim of the course

To make students conversant with wood as a source of energy and utilization of wood residues and chemicals for different purposes.

V. Theory

UNIT I

Energy and its measurements. Wood as sources of energy and its comparison with other sources. Criteria for evaluation of different fuel wood species for energy.

UNIT II

Utilization of wood waste material as fuel. Gasification, pyrolysis and briquetting of lignocellulosic material. Production of chemicals from forest biomass cellulose, lignin and hemicelluloses. Important wood extractives

UNIT III

Wood refinery techniques. Chemicals produced as by product in pulp industry.

UNIT IV

Destructive distillation of wood. Future of wood chemical industry.

VI. Suggested Reading

Dimitris SA. 2007. *Materials, Chemicals, and Energy from Forest Biomass*. American Chemical Society.

Klass DL. 1998. *Biomass for Renewable Energy, Fuels and Chemicals*. Academic Press.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press.

Sjostrom E. 1993. *Wood Chemistry: Fundamentals and Applications*. 2nd Ed. Gulf Professional Publishing, Texas.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Energy and its measurements	2
2.	Wood as sources of energy and its comparison with other sources	3
3.	Criteria for evaluation of different fuel wood species for energy	3
4.	Utilization of wood waste material as fuel	4
5.	Gasification, pyrolysis and briquetting of lignocellulosic material	3
6.	Production of chemicals from forest biomass cellulose, lignin and hemicelluloses. Important wood extractives	6
7.	Wood refinery techniques	4
8.	Chemicals produced as by product in pulp industry	3
9.	Destructive distillation of wood. Future of wood chemical industry	4
	Total	32

I. Course Title : Wood and Wood Technology

II. Course Code : FPU 703

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about advances in wood technology

V. Theory

UNIT I

Ultrastructure and composition of softwoods and hardwoods.

UNIT II

Transverse, volumetric and longitudinal shrinkages in wood.

UNIT III

Biopulping, enzyme pulp bleaching, biotechnological production of wood composites, bioremediation of wood treated with preservatives, bioactive wood polymer composites, non-conventional wood bonding, wood degradation by chemicals, treatment of pulp effluents.

VI. Practical

- Study of major cell types of softwoods and hardwoods;
- Cell inclusions. Shrinkage and swelling of wood;
- Determination of anti-shrink efficiency of treated wood. Pulping, pulp yield and bleaching.

VII. Suggested Reading

Bowyer JL Shmulsky R and Haygreen JG. 2010. *Forest Products and Wood Science: An Introduction*. 4th Ed. Blackwell Publishing.

David A and Talliman. 1978. *Wood as an Energy Resource*. Academic Press.

Hills WE. 1982. *Heartwood and Tree Exudates*. Springer Verlag.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press,Taylor and Francis Group.

Shmulsky RP and David. 2011. *Forest Products and Wood Science: An Introduction*. 6th Ed. Wiley, Blackwell.

Sjostrom E. 1993. *Wood Chemistry: Fundamentals and Applications*. 2nd Ed. Gulf Professional Publishing.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Ultrastructure and composition of softwoods and hardwoods	6
2.	Transverse, volumetric and longitudinal shrinkages in wood	6
3.	Biopulping, enzyme pulp bleaching	4
4.	Biotechnological production of wood composites	4
5.	Bioremediation of wood treated with preservatives, bioactive wood polymer composites, non-conventional wood bonding	8
6.	Wood degradation by chemicals, treatment of pulp effluents	4
	Total	32
	Practical	
1.	Study of major cell types of softwoods and hardwoods	5
2.	Cell inclusions. Shrinkage and swelling of wood	5
3.	Determination of anti-shrink efficiency of treated wood. Pulping, pulp yield and bleaching	6
	Total	16

I. Course Title : Analytical Techniques in Forest Products

II. Course Code : FPU 604

III. Credit Hours : 1+2

IV. Aim of the course

To develop understanding of students about advances in research methods

V. Theory

UNIT I

Concept of spectroscopy, electromagnetic radiation, Beer-Lambert Law of electromagnetic radiation. Chemical analysis of spectrophotometery. Different spectrophotometric methods in chemical analysis. Principle and utilization of different instruments based on spectrophotomeric methods- atomic absorption, spectrophotometer, IR, UV, NMR, Mass spectrophotometer, etc. Chromatography and various chromatographic techniques in chemical analysis of plant samples. Principle and utilization of various chromatographic techniques and instruments- TLC, HPLC, Gas chromatography, etc.

UNIT II

Principle and utilization of CHN analyzer. Physico-chemical analysis of pulp and Paper.

VI. Practical

- Estimation of volatile and non volatile chemical constituents of plants through various techniques and instruments;
- Estimation of different elements in plant samples. Chemical analysis of pulp;
- Determination of physico-chemical analysis of pulp and Paper;
- Preparation of research project. Writing of research report.

VII. Suggested Reading

Harborne JB. 1998. *Phyto-Chemical Method*s. 3rd Ed. Springer Publication, New York.

Moore WE and Johnson DB. 1967. *Procedure for Chemical Analysis of Wood and Wood Products.* Forest Products Laboratory, Forest Service US Dept of Agriculture.

Raaman N. 2006. *Phytochemical Techniques*. New India Publishing Agency, New Delhi.

Rao KP. 2003. *Pulp and Technology*. CBS Publishing and Distributors, New Delhi.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press, New York.

Rydholm SA. 1965. *Pulping Process*. Inter-science Publishers.

Snyder LR, Kirkland JJ and Glajch JL. 1997. *Practical HPLC Method Development*. 2nd Ed. John Wiley & Sons.

Wilde KD and Engewald W. 2014. *Practical Gas Chromatography: A Comprehensive Reference.* Springer, Berlin.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Concept of spectroscopy, electromagnetic radiation, Beer-Lambert Law of electromagnetic radiation. Chemical analysis of spectrophotometery. Different spectrophotometric methods in chemical analysis.	3
2.	Different spectrophotometric methods in chemical analysis. Principle and utilization of different instruments based on spectrophotomeric methods- atomic absorption, spectrophotometer, IR, UV, NMR, Mass spectrophotometer, etc.	5
3	Chromatography and various chromatographic techniques in chemical analysis of plant samples. Principle and utilization of various chromatographic techniques and instruments- TLC, HPLC, Gas chromatography, etc.	3
3.	Principle and utilization of CHN analyzer	2
4.	Determination of physico-chemical analysis of pulp and Paper	3
	Total	16

Practical

Sr. No	Topic	No. of Practical(s)
1.	Estimation of volatile and non volatile chemical constituents of plants through various techniques and instruments	8
2.	Estimation of different elements in plant samples	4
3.	Determination of physico-chemical analysis of pulp and Paper	6
4.	Preparation of research project. Writing of research report	14
	Total	32

I. Course Title : Chemistry of Medicinal and Aromatic Plants

II. Course Code : FPU 605

III. Credit Hours : 2+1

IV. Aim of the course

To expose the students on different aspects related to medicinal plants research and its application.

V. Theory

UNIT I

Detail study of biosynthetic pathways of terpenoides, steroids, alkaloids, phenolic compounds and amino acids.

UNIT II

Chemical studies of important insecticidal compounds of plant origin. Chemical conversion of some plant products to useful drugs.

UNIT III

Nature of postharvest degradation of active principles.

VI. Practical

- Extraction, purification, separation and structural determination of some important active principles of plants by various physical and chemical techniques;
- Structural determination of some important active principles of plants by various physical and chemical techniques.

VII. Suggested Reading

Chauhan NS. 1999. *Medicinal and Aromatic Plants of Himachal Pradesh*. Indus Publishing.

Mathe A. 2015. *Medicinal and Aromatic Plants of the World: Scientific, Production, Commercial and Utilization Aspects*. Springer.

Zohara Y and Bachrach U. 2005. *Handbook of Medicinal Plants*. CRC Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Detail study of biosynthetic pathways of terpenoides, steroids, alkaloids, phenolic compounds and amino acids	10
2.	Chemical studies of important insecticidal compounds of plant origin	6
3.	Chemical conversion of some plant products to useful drugs	8

Sr. No	Topic	No. of Practical(s)
4.	Nature of postharvest degradation of active principles	8
	Total	32

Practical

1.	Extraction, purification and separation of some important active principles of plants by various physical and chemical techniques	9
2.	Structural determination of some important active principles of plants by various physical and chemical techniques	7
	Total	16

I. Course Title : Processing Technology of Forest Products

II. Course Code : FPU 606

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about nutritional and post harvest aspects

V. Theory

UNIT I

Identification of harvesting period based on active content of drugs. Harvesting method of underground parts, leaves, stem, bark, wood, fruits, flowers, etc.

UNIT II

Processing of harvested crops of various forest products (*e.g.* Gums, Resin, Katha, Cutch, Tans, Dyes and fixed oil). Storage and value addition. Deterioration degradation of active principles during storage and their control.

UNIT III

Isolation of major bioactive compounds. Preparation of active content enriched extracts.

UNIT IV

Latest methods of extraction of volatile and fixed oil.

VI. Practical

- Harvesting, drying, grading and packaging of various forest products;
- Assessment of deterioration of active principles during storage and their control;
- Preparation of active content enriched extracts of important forest products.

VII. Suggested Reading

Bedi S, Singh T and Vyas SP. 2012. *A Handbook of Aromatic and Essential Oil Plants: Cultivation, Chemistry, Processing and Uses.* Agrobios (India).

Dawn CPA, Annamalai M and Naik R. 2016. *Leafy Medicinal Herbs: Botany, Chemistry, Postharvest Technology and Uses.* CABI.

Serdar O and Milan M. 2014. *Medicinal and Aromatic Crops: Harvesting, Drying and Processing.* CRC Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Identification of harvesting period based on active content of drugs	3
2.	Harvesting method of underground parts, leaves, stem, bark, wood, fruits, flowers, etc.	4
3.	Processing of harvested crops of various forest products (*e.g.* Gums, Resin, Katha, Cutch, Tans, Dyes and fixed oil)	5
4.	Storage and value addition	4
5.	Deterioration degradation of active principles during storage and their control	4
6.	Isolation of major bioactive compounds	5
7.	Preparation of active content enriched extracts	4
8.	Latest methods of extraction of volatile and fixed oil	3
	Total	32
	Practical	
1.	Harvesting, drying, grading and packaging of various forest products.	5
2.	Assessment of deterioration of active principles during storage and their control	5
3.	Preparation of active content enriched extracts of important forest products	6
	Total	16

I. Course Title : Value Additions and Marketing of Forest Products

II. Course Code : FPU 607

III. Credit Hours : 2+1

IV. Aim of the course

This course will educate students, methods of harvesting of yieldable plant/ plant parts of herb shrub, trees, etc. to increase the value of product, post harvest technology and will make them aware about instruments/ equipments used to extract essential oil and also operation of machines for preparation of tablets, mixture, tinctures, etc.

V. Theory

UNIT I

Value addition – concepts and procedures. Drying and grading of various forest products. Preparation of powders, aqueous and alcoholic extracts essences, etc. Preparation of tablets, mixtures, balms, ointments, etc. Bulk storage and packaging.

UNIT II

Basic and advanced concepts of trade and marketing, marketing under disorganized and organized sector. Village and regional markets, state, national and international market of forest products. Internet marketing practices for latest market value and other pattern of fluctuations for high value forest products. Concept of e-market and quality standards.

VI. Practical

- Visit to nearby pharmaceutical concern for understanding value addition processes;
- Visit to local market and data collection of sale and sale procedure – organized and unorganized. Internet surfing for latest market value of high value forest products.

VII. Suggested Reading

Govil JN, Arunachalam C and Singh VK. 2006. *Recent Progress in Medicinal Plants*. Volume11: drug development from molecules. Studium Press LLC.

Sharma AK and Singh VK, Govil JN and Goyal NK. 2006. *Recent Progress in Medicinal Plants*. Volume 12: Globalization Of Herbal Health. Studium Press LLC.

Singh MP and Somadey. 2015. *Indian Medicinal Plants*. Satish Serial Publishing House.

Singh VK, Govil JN and Singh G. 2002. *Ethnomedicine and Pharmacognosy*. Science Technology, Publishing LLC.

Syamal MM. 2008. *Production Technology of Medicinal and Aromatic Plants*. IBDC Publishers.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Value addition – concepts and procedures	3
2.	Preparation of powders, aqueous and alcoholic extracts, essences, etc.	5
3.	Preparation of tablets, mixtures, balms, ointments, etc. Bulk storage and packaging	6
4.	Basic and advanced concepts of trade and marketing, marketing under disorganized and organized sector	5
5.	Village and regional markets, state, national and international market of herbs and herbal forest products	5
6.	Internet marketing practices for latest market value and other pattern of fluctuations for high value forest products	6
7.	Concept of e-market and quality standards	2
	Total	32
	Practical	
1.	Visit to nearby pharmaceutical concern for understanding value addition processes	6
2.	Visit to local market and data collection of sale and sale procedure – organized and unorganized. Internet surfing for latest market value of high value forest products	10
	Total	16

I. Course Title : Modern Trends in Wood Modification

II. Course Code : FPU 608

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about advances in wood modification.

V. Theory

UNIT I

Engineered wood products. Wood polymer hybrid composites. Stabilization of wood preservatives.

UNIT II

Testing of biological performance of modified wood products. Degradation of cellular structure of wood during use.

UNIT III

Environmental issues related to wood modification.

VI. Practical

- Different preservative treatments of wood;
- Chemical modification of wood;
- Testing of biological performance of modified wood;
- Treated wood finishing.

VII. Suggested Reading

Ansell MP. 2015. *Wood Composites*. Elsevier-Science-Technology.

FAO. 2007. *Wood Preservation Manual*. International Book Distributor, Dehradun.

Hill CAS. 2006. *Wood Modification: Chemical, Thermal and Other Processes*. John Wiley and Sons Ltd.

Pizzi A and Mittal KL. 2011. *Wood Adhesives*. CRC Press.

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press.

USDA. 1999. *Wood Handbook – Wood as an Engineered Material*. US Department of Agriculture, Forest Service. Forest Products Laboratory, Madison.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Engineered wood products	5
2.	Wood polymer hybrid composites	7
3.	Stabilization of wood preservatives	5
4.	Testing of biological performance of modified wood products	6
5.	Degradation of cellular structure of wood during use	5
6.	Environmental issues related to wood modification	4
Total	32	
	Practical	
1.	Different preservative treatments of wood	5
2.	Chemical modification of wood	5
3.	Testing of biological performance of modified wood. Treated wood finishing	6
	Total	16

I. Course Title : Development in Pulp and Paper Technology

II. Course Code : FPU 609

III. Credit Hours : 2+0

IV. Aim of the course

To impart advanced knowledge related to different aspects of pulp and paper technology.

V. Theory

UNIT I

Historical development of the pulp and paper industry. Chemistry of fibrous raw material – raw material preparation.

UNIT II

Advances in pulping processes for softwood, hardwoods and other fibrous material. Recent trends in Bio-pulping, Chorine free bleaching, organo solve pulping.

UNIT III

Nenotechnology in pulp and paper making. Substation of wood with recycled fibers.

UNIT IV

Reduction in water utilization and effluent discharge.

VI. Suggested Reading

Rowell RM. 2013. *Handbook of Wood Chemistry and Wood Composites*. 2nd Ed. CRC Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Historical development of the pulp and paper industry	3
2.	Chemistry of fibrous raw material – raw material preparation	4
3.	Advances in pulping processes for softwood, hardwoods and other fibrous material	6
4.	Recent trends in Bio-pulping, Chorine free bleaching, organo solve pulping	7
5.	Nenotechnology in pulp and paper making	4
6.	Substation of wood with recycled fibers	4
7.	Reduction in water utilization and effluent discharge	4
	Total	32

I. Course Title : Application of Traditional Knowledge

II. Course Code : FPU 610

III. Credit Hours : 2+0

IV. Aim of the course

To develop understanding of students about application of traditional knowledge.

V. Theory

UNIT I

Traditional remedies for treating specific diseases like cardiovascular disease, mental disorders, rheumatic arthritis, diabetes, cough and asthma, fatigue, liver diseases, kidney and bladder stones, wounds stomach disorders, etc. Traditional therapies *vis-a-vis* modern therapies.

UNIT II

Scientific validation of traditional systems of medicines/ remedies – case studies. Important herbs used in traditional medicines. Integration of herbal remedies with allopathic system of medicine. Allopathic drugs based on medicines herbs.

UNIT III

National and international research and other institutions involved in scientific validation of traditional knowledge eg. CDRI, CIMAP, RRL's, CCRAS, WHO, etc., their role and major achievements.

UNIT IV

Composition of major herbal formulations e.g. Chavanprash, Vasavaleha, Arjunarishta, Pachakchurna, etc. Major herbal pharmaceutical companies and their products like Dabur, Zandhu, Baidyanath, Himalayan Drug Company, Charak Pharmaceuticals, etc. Role of local health traditions in primary health care.

VI. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture*. Vol. XI. Medicinal and aromatic plants. Malhotra Publ. House.

Gupta AK and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Johnson CB and Franz C. 2005. *Breeding Research on Aromatic and Medicinal Plants*. International Book Distr.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publ.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Traditional remedies for treating specific diseases like cardiovascular disease, mental disorders, rheumatic arthritis, diabetes, cough and asthma, fatigue, liver diseases, kidney and bladder stones, wounds stomach disorders, etc.	5
2.	Traditional therapies *vis-a-vis* modern therapies	3
3.	Scientific validation of traditional systems of medicines/ remedies – case studies	4
4.	Important herbs used in traditional medicines. Integration of herbal remedies with allopathic system of medicine	4
5.	Allopathic drugs based on medicines herbs	2
6.	National and international research and other institutions involved in scientific validation of traditional knowledge eg. CDRI, CIMAP, RRL's, CCRAS, WHO, etc., their role and major achievements	3
7.	Composition of major herbal formulations e.g. Chavanprash, Vasavaleha, Arjunarishta, Pachakchurna, etc.	4

Sr. No.	Topic	No. of Lecture(s)
8.	Major herbal pharmaceutical companies and their products like Dabur, Zandhu, Baidyanath, Himalayan Drug Company, Charak Pharmaceuticals, etc.	5
9.	Role of local health traditions in primary health care	2
	Total	32

I. Course Title : Production of Quality Planting Material of Medicinal and Aromatic Plants

II. Course Code : FPU 611

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about production of quality planting material.

V. Theory

UNIT I

Concept of quality in the context of medicinal and aromatic plants. Quality parameters of different medicinal and aromatic plants.

UNIT II

Role of genotype and environment in affecting quality. Selection and development of hybrids in medicinal and aromatic plants.

UNIT III

Breeders seed, foundation seed and certified seed. Marker assisted breeding. Authentication of nursery produce for quality parameters. Different approaches including biotechnological tools for production of quality planting material.

VI. Practical

- Production of inbred seed of commercially important species;
- Selection of superior genotypes on the basis of agronomical characters from an existing population of medicinal and aromatic plants;
- Evaluation of germplasm for yield attributes.

VII. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture*. Vol. XI. Medicinal and aromatic plants. Malhotra Publ. House.

Gupta AK and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Gupta AK, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants*.

Johnson CB and Franz C. 2005. *Breeding Research on Aromatic And Medicinal Plants*. International Book Distr.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publications.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Concept of quality in the context of medicinal and aromatic plants	2
2.	Quality parameters of different medicinal and aromatic plants	7
3.	Role of genotype and environment in affecting quality	4
4.	Selection and development of hybrids in medicinal and aromatic plants. Breeders seed, foundation seed and certified seed	6
5.	Marker assisted breeding	3
6.	Authentication of nursery produce for quality parameters	5
7.	Different approaches including biotechnological tools for production of quality planting material	5
	Total	32
	Practical	
1.	Production of inbred seed of commercially important species	5
2.	Selection of superior genotypes on the basis of agronomical characters from an existing population of medicinal and aromatic plants	6
3.	Evaluation of germplasm for yield attributes	5
	Total	16

I. Course Title : Processing Technology of Medicinal and Aromatic Plants

II. Course Code : FPU 612

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about nutritional and post harvest aspects of medicinal and aromatic plants.

V. Theory

UNIT I

Identification of maturity indices and harvesting period based on active content. Harvesting method of underground parts, leaves, stem, bark, fruits, flowers, etc.

UNIT II

Processing of harvested crops of medicinal and aromatic plants. Storage and value addition. Deterioration/ degradation of active principles during storage and their control.

UNIT III

Isolation of major bioactive compounds from medicinal plants, preparation of active content enriched extracts.

UNIT IV

Advances in extraction of essential oil.

VI. Practical

- Harvesting, drying, garbling, grading and packaging of medicinal and aromatic plants;
- Assessment of deterioration of active principles during storage and their control;
- Preparation of active content enriched extracts of important medicinal plants.

VII. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture.* Vol. XI. Medicinal and aromatic plants. Malhotra Publ. House.

Gupta AK and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Gupta AK, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants*.

Mann J 1994. *Chemical Aspects of Biosynthesis*. Oxford Chemistry Primers.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publ.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Identification of maturity indices and harvesting period based on active content	4
2.	Harvesting method of underground parts, leaves, stem, bark, fruits, flowers, etc.	4
3.	Processing of harvested crops of medicinal and aromatic plants	5
4.	Storage and value addition.	4
5.	Deterioration/ degradation of active principles during storage and their control	3
6.	Isolation of major bioactive compounds from medicinal plants, preparation of active content enriched extracts	8
7.	Advances in extraction of essential oil	4
	Total	32
	Practical	
1.	Harvesting, drying, garbling, grading and packaging of medicinal and aromatic plants	5
2.	Assessment of deterioration of active principles during storage and their control	6
3.	Preparation of active content enriched extracts of important medicinal plants	5
	Total	16

I. Course Title : Biosynthesis of Secondary Metabolites

II. Course Code : FPU 613

III. Credit Hours : 3+0

IV. Aim of the course

To develop understanding of students about biosynthesis of secondary metabolites.

V. Theory

UNIT I

Primary and secondary metabolites. Building blocks for secondary metabolites. Common reactions involved in the biosynthesis of secondary metabolites. Effect of environmental factors on production of secondary metabolites.

UNIT II

Biosynthetic pathways of terpenoids (mono, sesqui, di, tri and tetraterpenoids) and steroids.

UNIT III

Biosynthesis of alkaloids of phenylethylamine. Pyrrolidine piperidine, pyrrolidine – pyridine, tropane, quinoline, isoquinoline and phenanthrene groups.

UNIT IV

Biosynthesis of flavonoids, lignans (podophyllotoxin) and Vitamins E and K.

VI. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture*. Vol. XI. Medicinal and aromatic plants. Malhotra Publ. House.

Gupta K and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Gupta AK, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants.*

Mann J 1994. *Chemical Aspects of Biosynthesis*. Oxford Chemistry Primers.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publ.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Primary and secondary metabolites	4
2.	Building blocks for secondary metabolites	4
3.	Common reactions involved in the biosynthesis of secondary metabolites	7
4.	Effect of environmental factors on production of secondary metabolites	4
5.	Biosynthetic pathways of terpenoids (mono, sesqui, di, tri and tetraterpenoids) and steroids	8
6.	Biosynthesis of alkaloids of phenylethylamine. Pyrrolidine piperidine, pyrrolidine – pyridine, tropane, quinoline, isoquinoline and phenanthrene groups	10
7.	Biosynthesis of flavonoids, lignans (podophyllotoxin) and Vitamins E and K	8
	Total	45

I. Course Title : Value Additions and Marketing of Medicinal and Aromatic Plants

II. Course Code : FPU 614

III. Credit Hours : 2+1

IV. Aim of the course

This course will educate students, methods of harvesting of yieldable plant/ plant parts of herb, shrub, trees, climber, lianas and ephipytes. To increase the value of product, post harvest technology will be known to them, practical classes will make them aware about instruments/ equipments used to extract essential oil and also operation of machines for preparation of tablets, mixture, tinctures, etc.

V. Theory

UNIT I

Value addition for higher economic returns. Concepts and procedures. Preparation of powders, aqueous and alcoholic extracts, essences, etc. Preparation of tablets, mixtures, balms, ointments, etc. Bulk storage and packaging of medicinal and aromatic plants.

UNIT II

Basic and advanced concepts of trade and marketing, marketing under disorganized and organized sector. Village and regional markets, state, national and international market of herbs and herbal products. Internet marketing practices for latest market value and other pattern of fluctuations for high value medicinal and aromatic plants/ plant parts and products. Concept of e-market and quality standards.

VI. Practical

- Visit to nearby pharmaceutical concern for understanding value addition processes;
- Visit to local market and data collection on sale and sale procedure – organized and unorganized;
- Internet surfing for latest market value of high value of medicinal and aromatic plants.

VII. Suggested Reading

Alikhan I and Khanum A. 2008. *Role of Biotechnology in Medicinal and Aromatic Plants*. UKAZ Publishers.

Chadha KL and Gupta R. 2006. *Advances in Horticulture*. Vol. XI. Medicinal and aromatic plants. Malhotra Publ. House.

Gupta K and Sharma M. 2008. *Reviews on Indian Medicinal Plants*. ICMR.

Gupta AK, Tandon N and Sharma M. 2008. *Quality Standards of Indian Medicinal Plants*.

Mann J 1994. *Chemical Aspects of Biosynthesis*. Oxford Chemistry Primers.

Sharma R. 2004. *Agrotechniques of Medicinal Plants*. Daya Publ.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Value addition for higher economic returns. Concepts and procedures	4
2.	Preparation of powders, aqueous and alcoholic extracts, essences, etc.	5
3.	Preparation of tablets, mixtures, balms, ointments, etc. Bulk storage and packaging of medicinal and aromatic plants	5
4.	Basic and advanced concepts of trade and marketing, marketing under disorganized and organized sector	5
5.	Village and regional markets, state, national and international market of herbs and herbal products	5
6.	Internet marketing practices for latest market value and other pattern of fluctuations for high value medicinal and aromatic plants/ plant parts and products	6
7.	Concept of e-market and quality standards	2
	Total	32

Sr. No.	Topic	No. of Practical(s)
	Practical	
1.	Visit to nearby pharmaceutical concern for understanding value addition processes	6
2.	Visit to local market and data collection on sale and sale procedure – organized and unorganized. Internet surfing for latest market value of high value of medicinal and aromatic plants	10
	Total	16

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Forestry
– Forest Resource Management

Course Title with Credit Load
M.Sc. (Forestry) in Forest Resource Management

Course Code		Course Title	Credit Hours
		Major Courses	
FRM 501*	I	Forest Biometry and Management	2+1
FRM 502	II	Ecology and Management of Forest Soils	2+1
FRM 503*	I	Remote Sensing and Geographical Information System in Natural Resource Management	2+1
FRM 504	II	Land Use Planning and Watershed Management	2+1
FRM 505*	I	Forest Resource Economics	1+1
FRM 506*	II	Forest Ecosystem Services and Valuation	2+1
FRM 507	I	Environmental Impact Assessment and Auditing	1+1
FRM 508*	II	Forest Policy, law and International Conventions	2+0
FRM 509	I	Global Climate Change Impact, Mitigation and Adaptation	2+0
FRM 510*	II	Participatory Approaches in Forest Resource Management	1+1
FRM 511	I	Management of Tree Insect-Pests and Diseases	2+1
FRM 512	II	Forest Ecology, Biodiversity and Management	2+1
		Minor Courses	
		Courses from Silviculture and Agroforestry or Forest Biology and Tree Improveemnt or Forest Products and Utilization	08
		Supporting Courses	
FOR 511*	I	General Statistical Methods and Computer Applications	2+1
		Any other course relavent to MSc research problem	03
		Common Courses	
		Library and Information Services	1+0
		Technical Writing and Communications Skills	1+0
		Intellectual Property and its management in Agriculture	1+0
		Basic Concepts in Laboratory Techniques	1+0
		Agricultural Research, Research Ethics and Rural Development Programmes	1+0
FRM 591*	I/ II	Master's Seminar	1+0
		ii) Thesis Research	
FRM 599		Master's Research	0+30

*Compulsory Core Courses

Course Contents
M.Sc. (Forestry) in Forest Resource Management

I. Course Title : Forest Biometry and Management

II. Course Code : FRM 501

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge about forest management, ecosystem management, site quality evaluation, stand density and forest valuation, tree measurements, forest inventory and yield concepts

V. Theory

Unit I

Measurement of tree parameters. Estimation of volume, growth and yield of individual tree and forest stands. Preparation of volume tables and its application, yield and stand tables.

Unit II

Forest inventory, Sampling methods adopted in forestry, Use of GPS in forest inventory. Measurement of stand density. Simulation techniques.

Unit III

Principles of forest management; scope and object of forest management, ecosystem management, development of forest management in India. Site quality evaluation and importance. Stand density measurement.

Unit IV

Forest valuation and appraisal in regulated forests.

Unit V

Growth and yield prediction models – their preparation and applications.

VI. Practical

- Calculations of volume of felled as well as standing trees;
- Volume table preparation;
- Application of sampling procedures;
- Handling of GPS;
- Preparation of yield and stand table.

VII. Suggested Reading

Chaturvedi AN and Khanna LS. 1994. *Forest Menstruation*. International Book Distributor.
Davis LS and Johnson KN. 2005. *Forest Management*. Waveland Press.
Husch B, Miller CI and Beers TW. 2003.*Forest Menstruation*. John Wiley.
John AK, Ducey MJ, Beers TW and Husch B. 2017. *Forest Mensuration*. Wiley Blackwel.
Laar A Van and Akca A. 2007. *Forest Mensuration*. Springer, Netherlands.
Loctsch I and Haller KE. 1964. *Forest Inventory* Vol. and Vol II. BLV Verlagsgesellschaft, München, Germany.

Michacl S Philip. 1994. *Measuring Forests and Trees*. CAB International.
Prodan M. 1968. *Forest Biometrics*. Pergamn Press.
Ram Parkash. 1983. *Forest Surveying*. International Book Distr.
Sharpe GW, Hendee CW and Sharpe WE. 1986. *Introduction to Forestry*. McGraw-Hill.
Simmons CE. 1980. *A Manual of Forest Mensuration*. Bishen Singh Mahender Pal Singh, Dehradun.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Measurement of tree parameters. Estimation of volume, growth and yield of individual tree and forest stands	2
2.	Preparation of volume tables and their application	2
3.	Preparations of Yield and stand tables, their application	2
4.	Forest Inventory, Sampling methods adopted in Forestry, Kinds of enumeration, Kinds of sampling Advantages of sampling, Sampling design, Sampling Intensity and Sampling errorsUse of aerial Photography in Forest Inventory	5
5.	Use of GPS in Inventory	2
6.	Principles of forest management, scope and object of forest management	2
7.	Ecosystem management, development of forest management in India	2
	Site quality evaluation and importance: Site Index, Methods of site quality evaluation, Methods of determining past growth of stands Canopy Density, Crown Competition Factor	4
8.	Stand Density Measurement: Measure of stand density, Absolute measures of stand density, Stand density index, Stand density versus stocking	4
9.	Forest Valuation and appraisal in regulated forests	3
10.	Growth and yield prediction models- their preparation and applications	4
11.	Simulation techniques	2
	Total	36
	Practical	
1.	Calculations of volume of felled as well as standing trees	3
2.	Volume table preparation	4
3.	Application of sampling procedures	3
4.	Handling of GPS	2
5.	Preparation of yield and stand table	4
	Total	16

I. Course Title : Ecology and Management of Forest Soils

II. Course Code : FRM 502

III. Credit Hours : 2+1

IV. Aim of the course

To impart information on the soil types and properties of soils under different forest ecosystems, chemical and biological dimensions of soil fertility, and forest soil fertility evaluation and management.

IV. Theory

Unit I

Forest soils – distinguishing features, soils and vegetation development, physical and chemical properties- Types and properties of soils under different forest ecosystems.

Unit II

Forest floor – Organic horizons- litter dynamics- humus – types- organic matter decomposition-mineralization and immobilization of organic matter- nutrient cycling significance of C:N ratio, soil pH.

Unit III

Forest soil biology – soil fauna – nitrogen fixation – rhizobium-tree legume symbiosis *Frankia* x non-legume symbiosis, nitrification and denitrification in forest ecosystems. Micorrhizal associations in forest soils.

Unit IV

Nursery soils, problem soils, mineral nutrition, acidic deposition effects, fire effects and management interventions of forest soils.

VI. Practical

- Study of the soil profile;
- Mechanical analysis;
- Determination of pH;
- Organic C, CEC and available,
- Micro and macro nutrients;
- Manurial schedules for different soils.

VII. Suggested Reading

Brady NC and Weil RR. 2007. *The Nature and Properties of Soils*. 14th Ed., Prentice

Fisher RF and Binkley D. 2000. *Ecology and Management of Forest Soils*. John Wiley & Sons, Inc. New York.

Hall, New Jersey.

Stevenson FJ and cole MA. 1999. *Cycles of soil; Carbon, Nitrogen, Phosphorus, Sulphur, micronutrients*. John Wiley & Sons Inc. New York.

Tisdale LS, Nelson LW and Beaton JD. 1985. *Soil Fertility and Fertilizers*. Macmillan Publishing Company, New York.

Troeh FR and Thompson LM. 2005. *Soils and Soil Ferility*. Black well.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Forest soils – distinguishing features – soils and vegetation development	3
2.	Physical and chemical properties- Types and properties of soils under different forest ecosystems	3
3.	Forest floor: Organic horizons and litter dynamics	3
4.	Humus – types- organic matter decomposition-mineralization and immobilization of organic matter	4
5.	Nutrient cycling, significance of C:N ratio, soil pH	3
6.	Forest soil biology, soil fauna, nitrogen fixation. Rhizobium-tree legume symbiosis. *Frankia* x non-legume symbiosis	4

Sr. No	Topic	No. of Lecture(s)
7.	Nitrification and denitrification in forest ecosystems. Micorrhizal associations in forest soils	3
8.	Nursery soils, problem soils, mineral nutrition, acidic deposition effects	5
9.	Effect of forest fire and management interventions of forest soils	4
	Total	32
	Practical	
1.	Study of the soil profile	1
2.	Mechanical analysis of soil	3
3.	Determination ofpH, EC, organic carbon	2
4.	Determination ofCEC	2
5.	Determination of availableN, P, K, Ca, Mg and S	3
6.	Determination of micro-nutrients-Cu, Zn, Mn and Fe	2
7.	Manurial schedules for different soils	3
	Total	16

I. Course Title : Remote Sensing and Geographical information System in Forest resource management

II. Course Code : FRM 503

III. Credit Hours : 2+1

IV. Aim of the course

To impart practical knowledge to the students on geomatics and its application in natural resource management

V. Theory

Unit I

Satellite remote sensing and recent developments in geomatics, different satellite missions of India and abroad. Spatial and spectral resolution of different data products and applications.

Unit II

Geo-referencing of topo-sheets and satellite imageries, Satellite Image Interpretation, Digital Image Processing (DIP)-image registration, image enhancement, classification, supervised and unsupervised classification.

Unit III

RS softwares, Application of Remote Sensing in forest resource management-land-use and land cover mapping, vegetation mapping and change detection, forest biomass and carbon mapping and monitoring, forest damage as sessment (pests and diseases, mining, fire), forest fire risk zonation and mapping, Watershed delineation and mapping, wildlife habitat assessment, etc.

Unit IV

GIS for the collection, storage and spatial analysis for geo-referenced forest resources data and information. Integration of spatial data analysis systems with knowledge-based systems and/ or simulation systems for the development of information/ decision support systems for forest management. GIS application in FRM.

VI. Practical

- Thematic layers build up, overlaying and their integration using ERDAS and Arc GIS software package;
- Interpretation of satellite data and digital image processing;
- Preparation of thematic maps;
- Preparation forest biomass and carbon map, fire affected areas assessment, preparation of change detection map, classification of LULC using ERDAS and Arc GIS softwares.

VII. Suggested Reading

A Preliminary Overview. *Journal of Latin American Geography*.

Bolstad P. 2005. *GIS Fundamentals: A first text on Geographic Information Systems, Second Edition*. White Bear Lake, MN: Eider Press.

Buzai GD and Robinson D. 2010. *Geographical Information Systems in Latin America*, 1987-2010.

Campbell JB and Randolph HW. 2011. *Introduction to Remote Sensing*. Fifth Edition, The Guild Press, New York.

Chang K. 2007. *Introduction to Geographic Information System, 4th Edition*. McGraw Hill.

Elangovan N. 2006. *GIS Fundamentals, applications and implementation*. New India Publ.Agncy, New Delhi.

Gurugnanam B. 2009. *Geographic Information System*. New India Publ. Agency, New Delhi.

Harvey and Francis. 2008. *A Primer of GIS, Fundamental geographic and cartographic concepts*. The Guilford Press.

Jackson MJ. 1992. *Integrated Geographical Information Systems*. International Journal of Remote Sensing.

Joseph G. 2005. *Fundamentals of Remote Sensing*, Second edition. Universities Press.

Lillesand TM and Kiefer WR. 1994. *Remote sensing and Image Interpretation*, Fourth edition. John Wiley & Sons, Inc., USA.

Reddy AM. 2014. *Text book of Remote Sensing and Geographic Information System*. 4th edition, BS Publication, Hyderabad.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Remote sensing: Introduction, definition, brief history, fundamental principle of RS, Stages of RS, Classification of RS: Active and Passive RS- based on source of energy and wavelength; Aerial and space remote sensing, Merits and limitations of RS. Recent developments in geomatics. Different satellite missions of India and abroad	6
2.	Remote sensing platforms-ground aerial and space platforms, satellite orbits, Resolution- spatial, spectral, radiometric and temporal; Scanning systems- whisk broom and push broom scanners; Sensor system- MSS, ETM, MSS, LISS, etc.	6
3.	Image analysis: Definition, visual image analysis, digital image analysis, elements of image analysis and steps in digital image processing. Agencies involved in remote sensing	4
4.	Application of RS in forestry: Vegetation cover classification and mapping-NDVI, SAVI, EVI, status and monitoring, species identification, social and agro-forestry applications, growing stock estimation, biodiversity characterization, wildlife habitat	

Sr. No	Topic	No. of Lecture(s)
	suitability mapping, biomass and carbon mapping, etc.	6
5.	Geoinformatics and GIS meaning, objectives, elements of GIS-software, hardware, data ware, human ware, processes involved in GIS, Raster data, vector data, thematic overlay building. Application of GIS to forest resource management	5
6.	GPS: Global Positioning System-meaning, principles, applications, GNSS, IRNS, GAGAN, etc.	3
	Total	30

Practical

1.	Thematic layers build up, overlaying and their integration using ERDAS and ArcGIS Software package	4
2.	Interpretation of satellite data and digital image processing	4
3.	Preparation of thematic maps	3
4.	Preparation forest biomass and carbon map, fire affected areas assessment, preparation of change detection map, classification of LULC using ERDAS and ArcGIS softwares	5
	Total	16

I. Course Title : Land Use Planning and Watershed Management

II. Course Code : FRM 504

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of students about land use planning and watershed management. Developing sustainable agroforestry systems/ techniques in watershed.

V. Theory

Unit I

Land use Planning: Concepts and techniques; Agro-ecological regions/ sub-regions of India; factors affecting land use; soil and land use survey through remote sensing techniques.

Unit II

Interpretation of soil resource map for land use planning; land evaluation methods and soil-site suitability evaluation for different crops.

Unit III

Watershed management concept- objectives, characterization, planning, execution, community participation and evaluation.

Unit IV

Developing economically and ecologically sustainable agroforestry systems for watersheds; water harvesting and its efficient use; rehabilitation of watersheds. Suitable tree planting techniques in watersheds. Suitable trees/ shrubs and grasses for watershed for different agro-climatic regions.

Unit V

Watershed management cases studies. Drought and flood mapping and its relevance in designing sustainable cropping systems.

VI. Practical

- Study of Agro-ecological regions/ sub-regions of India;
- Soil and land use survey through remote sensing technique;
- Interpretation of soil resource map for land use planning; land evaluation methods and soil-site suitability evaluation for different crops;
- Watershed characterisation, planning, execution, community participation and evaluation.Suitable tree planting techniques in watersheds;
- Suitable trees/ shrubs and grasses for watershed for different agro-climatic regions.
- Watershed management cases studies;
- Drought and Flood mapping and its relevance in designing sustainable cropping systems.

VII. Suggested Reading

Michael AM and Ojha TP. 1966. *Principles of Agricultural Engineering*, Jain Brothers, Jodhpur.
Michael AM. 2008. *Irrigation Theory and Practice*. Vikas Publishing House Pvt Ltd.
Murthy JVS. 1998. *Watershed Management*. New Age International, New Delhi.
Murthy VVN. 1985. *Land and water management engineering*. Kalyani Publishers, New Delhi.
Narayana DVV, G Sastry and US Patnaik. 1997. *Watershed Management*. Indian Council of Agricultural Research, New Delhi.
Narayana DVV. 1993. *Soil and Water Conservation Research in India*, ICAR, New Delhi.
Singh G *et al*. 1988. *Manual of Soil and Water Conservation*. Oxford IBH Publishing Co. New Delhi.
Subramanya K. 2006. *Engineering Hydrology*, Tata McGraw Hill publication.
USDA. 1961. *A Manual on Conservation of Soil and Water*. Oxford and IBH Publishing Company.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Land use Planning: concepts and techniques; Agro-ecological regions/ sub-regions of India	3
2.	Factors affecting land use; soil and land use survey through remote sensing technique	3
3.	Interpretation of soil resource map for land use planning	2
4.	Land evaluation methods and soil-site suitability evaluation for different crops	4
5.	Watershed management concept- objectives, characterization, planning, execution, community participation and evaluation	5
6.	Developing economically and ecologically sustainable agroforestry systems for watersheds; water harvesting and its efficient use; rehabilitation of watersheds	4
7.	Suitable tree planting techniques in watersheds	2
8.	Suitable trees/ shrubs and grasses for watersheds for different agroclimatic regions	2
9.	Watershed management cases studies	4
10.	Drought and flood mapping and its relevance in designing sustainable cropping systems	3
	Total	32

Sr. No.	Topic	No. of Practical(s)
	Practical	
1.	Study of Agro-ecological regions/ sub-regions of India	2
2.	Soil and land use survey through remote sensing technique	2
3.	Interpretation of soil resource map for land use planning; land evaluation methods and soil-site suitability evaluation for different crops	3
4.	Watershed characterisation, planning, execution, community participation and evaluation. Suitable tree planting techniques in watersheds	3
5.	Suitable trees/ shrubs and grasses for watershed for different agro-climatic regionsWatershed management cases studies	3
6.	Drought and Flood mapping and its relevance in designing sustainable cropping systems	3
	Total	16

I. Course Title : Forest Resource Economics

II. Course Code : FRM 505

III. Credit Hours : 1+1

IV. Aim of the course

To develop understanding of students about forest resource management and economics management decisions, forest and environmental resource accounting.

V. Theory

Unit I

Principles of microeconomics and its application in forest resource management. Demand, supply and marketing of forest products. Theory of capital and application in forest resource management.

Unit II

Domestic and international trade in forest products. Impact of soicio-economic variables on forest appraisal and management decisions. Externalities and property rights.

Unit III

Natural and environmental resource accounting –methods and implications. Application of operational research tools in evaluating forest management alternatives in public and private forest planning and valuation.

VI. Practical

- Exercises on estimation of demand and supply functions;
- Biodiversity valuation, valuation of non-marketed forest products;
- Exercises on financial and economic appraisal of forestry projects;
- Exercises on marketing of forest products and international trade competitiveness;
- Computer applications for using programming techniques in evaluating forest management alternatives.

VII. Suggested Reading

FAO. 1986. *Guidelines to Practical Project Appraisal*. Natraj Publ.

Kerr JM, Marothia DK, Singh K, Ramaswamy C and Beritley WR. 1997. *Natural Resource Economics: Theory and Applications in India*. Oxford and IBH.

Nautiyal JC. 1988. *Forest Economics – Principles and Applications*. Natraj Publications, Dehradun.

Sharma LC. 1980. *Forest Economics, Planning and Management*. International Book Distributors, Dehradun.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Principles of microeconomics and its application in forest resource management	3
2.	Demand, supply and marketing of forest products. Theory of capital and application in forest resource management	4
3.	Domestic and international trade in forest products	1
4.	Impact of soicio-economic variables on forest appraisal and management decisions. Externalities and property rights	3
5.	Forest and environmental resource accounting –methods and implications.	3
6.	Application of operational research tools in evaluating forest management alternatives in public and private forest planning and valuation	3
	Total	17
	Practical	
1.	Exercises on estimation of demand and supply functions	4
2.	Biodiversity valuation, valuation of non-marketed forest products	3
3.	Exercises on financial and economic appraisal of forestry projects Exercises on marketing of forest products and international trade competitiveness	6
4.	Computer applications for using programming techniques in evaluating forest management alternatives	3
	Total	16

I. Course Title : Forest Ecosystem Services and Valuation

II. Course Code : FRM 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge ecosystem services, natural capital, natures contribution to people, global science perception on ecosystem services, quantification and valuation tools, governance, challenges and policy issues. To develop an understanding of students on the concepts of Ecological-Economics and importance of Green Economy.

V. Theory

Unit I

Ecosystem Services (ES) basics, importance, history of ES and natural capital, classification of ES-provisioning, regulating, supporting and cultural services and their status and changes, drivers of change of ecosystem services, international conventions and charters on ES-Inter-governamental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) and Millennium Ecosystem Services (MEA) Assessment– an overview. Linkages among biodiversity, ecosystem services and human well being.

Unit II

Quantification of ecosystem services-direct and indirect approaches. Ecological Economics: Valuation of ES, need for valuation. Use values and Non-Use values-direct value, indirect value, optional value, bequest value, existence value. Valuation methods-Market price based approach such as stumpage value method, productivity and cost based approaches such as replacement cost method and surrogate market and stated preference approaches such as stumpage value method, Hedonic Pricing Method, Contingent Valuation Method, Travel Cost Method, etc., Case studies in India and abroad. Challenges in valuation of ES.

Unit III

Governance and policy issues in ecosystem services, Payment for ecosystem services (PES), mechanisms of benefit sharing, eco-certification, Geographic Indications, Forest Stewardship Council, Landscape labelling. National and International initiatives in PES and on-going programs.

VI. Practical

- IPBES and MEA assessment;
- Valuation methods- direct and indirect;
- Case studies of PES in India and Abroad;
- Case studies on certification and geographical indications, FSC.

VII. Suggested Reading

Alavalapati JRR, Shrestha RK, Stainback GA and Matta JR. 2004. *Agroforestry development: An environmental economic perspective*. Agroforestry Systems.

Huxley P. 1999. *Tropical Agroforestry*. Blackwell.

Jain SK and Singh P. 2000. *Economic Analysis of Industrial Agroforestry: Poplar (Populus deltoides) in Uttar Pradesh (India)*. Agroforestry Systems.

Jeffers JNR. 1978. *An Introduction to System Analysis with Ecological Application*. Edward Arnold.

Jose S. 2009. *Agroforestry for Ecosystem Services and Environmental Benefits: an Overview*. Agroforestry Systems.

Nair PKR. 1993. *An Introduction to Agroforestry*. Kluwer, Netherlands.

Paulo ELD and Nunes. 2014. *Handbook on the Economics of Ecosystem and Biodiversity*. E-book.

Sander J, Nicolas D and Hans K. 2014. *Ecosystem Services: Global Issues and Local Practices*. First Edition. Elsevier Publications.

Schroth G and Sinclair F. 2003. *Tree Crops and Soil Fertility: Concepts and Research Methods*, CABI, Wallingford, UK.

Young A. 1997. *Agroforestry for Soil Management*. 2nd ed. CABI, Wallingofrd, UK.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Ecosystem Services (ES) basics, importance, history of ES and natural capital, classification of ES-provisioning, regulating, supporting and cultural services	3

Sr. No	Topic	No. of Lecture(s)
2	Status and changes of ecosystem services, drivers of change of ecosystem services	2
3	International conventions and charters on ES-Inter-governmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) and Millennium Ecosystem Services (MEA) Assessment– an overview	3
4.	Linkages among biodiversity, ecosystem services and human well being	2
5.	Quantification of Ecosystem Services-direct and indirect approaches. Ecological Economics: Valuation of ES, need for valuation	4
6.	Use values and Non-Use values- direct value, indirect value, optional value, bequest value, existence value	2
7.	Valuation methods-Market price based approach such as stumpage value method, productivity and cost based approaches such as replacement cost method and surrogate market and stated preference approaches such as stumpage value method, Hedonic Pricing Method, Contingent Valuation Method, Travel Cost Method, etc.	6
8.	Case studies of valuation of ES in India and abroad. Challenges in valuation of ES	2
9.	Governance and policy issues in ecosystem services	2
10.	Payment for ecosystem services (PES), mechanisms of benefit sharing, eco-certification, Geographic Indications, Forest Stewardship Council, Landscape labelling	3
11.	National and International initiatives in PES and on-going programs	3
	Total	32

Practical

Sr. No	Topic	No. of Practical(s)
1.	IPBES and MEA assessment	3
2.	Valuation methods- direct and indirect	3
3.	Case studies of PES in India and Abroad	4
4.	Case studies on certification and geographical indications, FSC	4
	Total	16

I. Course Title : Environmental Impact Assessments and Auditing

II. Course Code : FRM 507

III. Credit Hours : 1+1

IV. Aim of the course

To provide a detailed knowledge on the environmental inmpact assessment and its importance. Also this course enables the students to know salient features of EIA legislation and other statutory obligations.

V. Theory

Unit I

Origin of EIA and historical perspective, scope and purpose of EIA; Key merits of environmental assessment in regulating the state of environment. Global experience in EIA; Comparative review of EIA systems in different countries and regions. Salient features of EIA legislation and other statutory obligations. · Environmental decision making in India Environmental clearance procedures and national requirements.

Unit II

Flow charts showing key steps; Methodological approaches and tools for key stages in the process: Screening (classification of developments and stage to determine the level of EIA, exclusion and inclusion lists of projects, different approaches to screening) Scoping (scoping steps, guidance and tools, and stakeholder involvement), Impact prediction and evaluation (approach for baseline development and methods of impact identification-checklists, Matrices, Networks).

Unit III

Introduction to various impact assessment methods: checklist, matrices, networks, indices and weight scaling techniques and their scope and limitations · Prediction and assessment of impact on the land, air, water, noise, biological and socioeconomic environments Mitigation: definitions and hierarchy of measures including avoidance, reduction, rectification and compensation enhancement approaches, principles and concepts of offsets, type of offsets.

Unit IV

EIA administration and practice. Cost and benefits of evaluation of EIA; understanding strengths and limitation of EIA. EIA standards; risk assessment; potential impact to water and air pollution.

VI. Practical

- Methodological approaches and tools for key stages in the process: Screening (classification of developments and stage to determine the level of EIA, exclusion and inclusion lists of projects, different approaches to screening) Scoping (scoping steps, guidance and tools, and stakeholder involvement);
- Impact prediction and evaluation (approach for baseline development and methods of impact identification-checklists, Matrices, Networks), EIA of development projects, EIA of restored mine lands, Undertaking an EIA: case studies for agro-industries.

VII. Suggested Reading

Anjanayulu Y. 2002. *EIA Methodologies*. BSP BS publication

Lawrence and Dravid P. 2003. *EIA Practical Solutions to Recurrent problems*.

Morgan RK. 1988. EIA- *A methodological Perspective*. Kluwer Academic Publishers.

Patnaik and Naba Kumar. 2000. *Environmental Audit-A Perspective, Environment Management and Audit*, Deep and Deep Publication Pvt. Ltd., New Delhi.

Pramanik AK. 2002. *Environmental Audit and Indian Scenario, Environmental Accounting and Reporting*, Deep and Deep Publications Pvt. Ltd., New Delhi.

Selvam M. 2002. *The Need for an Environmental Audit, Environmental Accounting and Reporting*, Deep and Deep Publications Pvt. Ltd., New Delhi.

Smith LG. 1993. *Impact Assessment and Sustainable Resource Management*, John Wiley & Sons. New York.

Shrivastava AK. 2003. *Environment Auditing*. APH Publishing.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Origin of EIA and historical perspective, scope and purpose of EIA. Key merits of environmental assessment in regulating the state of environment	1
2.	Global experience in EIA; Comparative review of EIA systems in different countries and regions. Salient features of EIA legislation and other statutory obligations	2
3.	Environmental decision making in India Environmental clearance procedures and national requirements	2
4.	Flow charts showing key steps; Methodological approaches and tools for key stages in the process: Screening (classification of developments and stage to determine the level of EIA, exclusion and inclusion lists of projects, different approaches to screening	2
5.	Scoping (scoping steps, guidance and tools, and stakeholder involvement), Impact prediction and evaluation (approach for baseline development and methods of impact identification-checklists, Matrices, Networks)	2
6.	Introduction to various impact assessment methods: checklist, matrices, networks, indices and weight scaling techniques and their scope and limitations	2
7.	Prediction and assessment of impact on the land, air, water, noise, biological and socioeconomic environments	2
8.	Mitigation: definitions and hierarchy of measures including avoidance, reduction, rectification and compensation enhancement approaches	2
9.	Principles and concepts of offsets, type of offsets	2
	Total	17
	Practical	
1.	Methodological approaches and tools for key stages in the process: Screening (classification of developments and stage to determine the level of EIA, exclusion and inclusion lists of projects, different approaches to screening) Scoping (scoping steps, guidance and tools, and stakeholder involvement)	8
2.	Impact prediction and evaluation (approach for baseline development and methods of impact identification-checklists, Matrices, Networks), EIA of development projects, EIA of restored mine lands, Undertaking an EIA: case studies for agro-industries	8
	Total	16

I. Course Title : Forest Policy, Law and International Conventions

II. Course Code : FRM 508

III. Credit Hours : 2+0

IV. Aim of the course

To develop understanding of students about forest policy and laws and international conventions

V. Theory

Unit I

Forest policy – Relevance and scope; National Forest Policy – 1894, 1952 and 1988

Unit II

Forest laws; Indian Forest Act 1927, general provision and detailed study; Forest Conservation Act, 1980, Wildlife Protect Act, 1972 Important Forest Rules and Guidelines; Indian evidence act applied to forestry matters, Legal definitions; objectives of species forest laws.

Unit III

History of environmental policy in India. Constitutional and legislative provisions—constitutional provisions and the environment, Environmental protection and fundamental rights, Digest of environmental *legislation* (Interpretation of environmental statutes, Environmental protection Act, 1986; Biodiversity Act, 2002, Schedules tribes (Recognition of forest rights), Act, 2007. Judicial remedies and procedures, public interest litigations, Intellectual Property Rights (Patents, Copy rights, Trade mark, Trade secrets), freedom of information, and right to know.

Unit IV

Important case studies and landmark judgments. Case studies of different forests divisions/ areas of India. International conventions of forestry issue. e.g. Role of internationaltreaties like CITES, IUCN, RAMSER, CBD, etc.

VI. Suggested Reading

Divan S and Rosencranz A. 2002. *Environmental Law and Policy in India*. Oxford University Press, New Delhi.

Indian Forest Acts (with short notes)1975. Allahabad Law Agency.

Jha LK. 1994. *Analysis and Appraisal of India's Forest Policy*. Ashish Publ. House.

National Forest Policy 1952. Ministry of Food and Agriculture, New Delhi.

National Forest Policy 1988. Ministry of Environment and Forests, New Delhi.

Negi SS. 1985. *Forest Law*. Natraj Publishers.

Saharia VB. 1989. *Wildlife Law in India*. Natraj Publ.The Biodiversity Act,2002.

Wilson B, Van Kooten GC, Vertinsky I, Arthur L. 1998. *Forest policy —International case studies*. CABI publishing, UK.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Forest policy – Relevance and scope,National Forest Policy – 1894, 1952 and 1988	2
2.	Forest laws; Indian Forest Act –1927, general provision and detailed study	3
3.	Forest Conservation Act, 1980	2
4.	Wildlife Protect Act, 1972	2
5.	Important Forest Rules and Guidelines.; Indian evidence act applied to forestry matters, Legal definitions; objectives of species forest laws	2
6.	History of environmental policy in India	1
7.	Constitutional and legislative provisions—constitutional provisions and the environment,	2

Sr. No	Topic	No. of Practical(s)
8.	Environmental protection and fundamental rights, Digest of environmental *legislation*(Interpretation of environmental statutes,	2
9.	Environmental protection Act, 1986	2
10.	Biodiversity Act, 2002	2
11.	Schedules tribes (Recognition of forest rights), Act,2007	1
12.	Judicial remedies and procedures, public interest litigations, Intellectual Property Rights (Patents, Copy rights, Trade mark, Trade secrets), freedom of information, and right to know	4
13.	Important case studies and landmark judgments. Case studies of different forests divisions/ areas of India	3
15.	International conventions of forestry issue. e.g. Role of international treaties like CITES, IUCN, RAMSER, CBD, etc.	3
	Total	32

I. Course Title : Global Climate Change Impact, Mitigation and adaptation

II. Course Code : FRM 509

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge on climate change and different mitigation and adaptation strategies and also on international initiatives on climate change.

V. Theory

Unit I

Definition and concept of climate change and variability; global warming and dimming; science and politics of climate change and international conventions; evidence, scenario and causes of climate change. Greenhouse gases and mechanism of their production and emission from various agro-ecosystems, source and sinks of GHG; warming potential and contribution of greenhouse gases to global warming, greenhouse effect; monitoring of greenhouse gases.

Unit II

Impact assessment of rise in atmospheric temperature and CO_2 on growth, physiological processes, productivity and quality of different vegetation types, soil health, water availability, insect pest dynamics, crop production, milk and inland and marine fish production; climate change and loss of biodiversity; spatial and temporal changes in forest and plantation productivity and agricultural production in context of climate change.

Unit III

Adaptation and mitigation options to climate change; carbon sequestration; modeling climate change and its impact on forests. International summit, conferences, protocols and negotiations on climate change; clean development mechanism; carbon trading, credits, footprints and govt. strategies and policies on climate change management.

Unit IV

Recent techniques for assessing the impact of high temperature on tree species and crops, recent techniques for assessing the impact of CO_2 fertilization on productivity, recent techniques for assessing the impact of elevated CO_2 on tree species.

VI. Suggested Reading

Climate Change: Challenges To Sustainable Development in India. 2008. Research Unit (Larrdis) Rajya Sabha Secretariat, New Delhi.

Reddy KR and Hodges HF. *Greenhouse Gas Emission from Agricultural System*, Published by IPCC- USEPA *Climate change and global crop productivity* Ed. CABI Publishing.

IPCC Assessment Report. 2007. *Climate Change Journal Climate Change: Source, Impact and Policy*, Proceeding of 2nd World Climate Conference. Ed. by J Jager and HL. Ferguson, Cambridge University Press.

Houghton J. *Global Warming* (4th), Cambridge Press.

Robert M, Clausen and Henry L Gholz. *Carbon and Forest Management*. School of Forest Resources and Conservation. University of Florida, Gainesville, FL 32611, USA.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Definition and concept of climate change and variability; global warming and dimming	2
2.	Science and politics of climate change and international conventions; evidence, scenario and causes of climate change. Greenhouse gases and mechanism of their production and emission from various agro-ecosystems, source and sinks of GHG	4
3.	Warming potential and contribution of greenhouse gases to global warming, greenhouse effect; monitoring of greenhouse gases	4
4.	Impact assessment of rise in atmospheric temperature and CO_2 on growth, physiological processes, productivity and quality of different forest types, soil health, water availability, insect pest dynamics, crop-weed competition, milk and inland and marine fish production	4
5.	Climate change and loss of biodiversity; spatial and temporal changes in forest and plantation productivity and agricultural production in context of climate change	3
6.	Adaptation and mitigation options to climate change; carbon sequestration; modeling climate change and its impact on forests	4
7.	International summit, conferences, protocols and negotiations on climate change; clean development mechanism; carbon trading, credits, footprints	3
8.	Government strategies and policies on climate change management	3
9.	Recent techniques for assessing the impact of high temperature on tree species and crops, recent techniques for assessing the impact of CO_2 fertilization on productivity, recent techniques for assessing the impact of elevated CO_2 on tree species	5
	Total	32

I. Course Title : Participatory Approaches in Forest Management

II. Course Code : FRM 510

III. Credit Hours : 1+1

IV. Aim of the course

To inculcate knowledge and skills in students to employ participatory tools and techniques for effective planning, implementation, monitoring and evaluation of forestry projects, to efficiently carry out forest resource management and to effectively resolve conflicts by adopting participatory techniques.

V. Theory

Unit I

Participatory approaches- Participatory planning- Participatory data collection, research and project preparation; Participatory implementation- group approaches for implementation of projects and programmes; Participatory monitoring; Participatory evaluation- Concurrent and ex-post evaluation; Peoples' participation-community mobilization.

Unit II

Concept of Social Research, Traditional methods of doing research, Action Research and Participatory Research. Scope and importance of Qualitative Data. Construction and Methods of Data Collection. Different types of Sampling. Interview Techniques. Qualitative methods-Sociometry, Case Studies, observation, coding and content analysis.

Unit III

Participatory Methods of Data Collection-Concept and Need of Data, Information, Appraisal; Various methods of Data Collection, Interpretation of Qualitative and Quantitative Data. Origin of Participatory Methods, FSA, Rapid Rural Appraisal. Key informants, selection of key informants.Semi-structured interviews, Question guide/ checklist and other relevant methods and their applications in forestry and natural resource management.

Unit IV

Objectives of PRA.The Logic and merits of the PRA.Challenges/ constraints of PRA. Major methods of PRA. The fundamental concepts of PRA. Principles of PRA. Operational guidelines for organizing PRA at village level. PRA and PLA – Concept, Methods, Tools, Interpretation and Techniques. Other relevant participatory approaches like RRA, PANR, etc. Emerging tools used for PRA (ICT, GIS, GPS, etc.).

VI. Practical

- Visit to selected forest areas to undertake and understand various participatory research methods including participatory rural appraisal techniques like social mapping, resource mapping, Venn diagrams, transect walk, time lines, etc.

VII. Suggested Reading

Kothari CR. 1992. *Research Methodology- Methods and Techniques*. Wiley Eastern Limited New Delhi.

Narayanasamy N. 2008. *Participatory Rural Appraisal: Principles, Methods and Application*.

Robert C. 1981. *Rapid Rural Appraisal Rationale and Repertoire*. IDS Discussion Paper, No. 155, IDS, Sussex.

Sabarathnam VE. 2002. *R/ R/ PRA for Agriculture*.Vamsaravath Publishers, Hyderabad.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Participatory approaches- Participatory planning- Participatory data collection, research and project preparation	2
2.	Participatory implementation- group approaches for implementation of projects and programmes; Participatory monitoring; Participatory evaluation- Concurrent and ex-post evaluation; Peoples' participation- community mobilization	2
3.	Concept of Social Research, Traditional methods of doing research, Action Research and Participatory Research	2
4.	Impact assessment of rise in atmospheric temperature and CO2 on growth, physiological processes, productivity and quality of different forest types, soil health, water availability, insect pest dynamics, crop-weed competition, milk and inland and marine fish production	2
5.	Scope and importance of qualitative data. Construction and Methods of Data Collection. Different types of Sampling	2
6.	Interview Techniques. Qualitative methods-Sociometry, Case Studies, observation, coding and content analysis	2
7.	Participatory Methods of Data Collection-Concept and Need of Data, Information, Appraisal; Various methods of Data Collection, Interpretation of Qualitative and Quantitative Data	2
8.	Origin of Participatory Methods, FSA, Rapid Rural Appraisal. Key informants, selection of key informants. Semi-structured interviews, Question guide/ checklist and other relevant methods and their applications in forestry and natural resource management	2
9.	Objectives of PRA. The Logic and merits of the PRA. Challenges/ constraints of PRA. Major methods of PRA. The fundamental concepts of PRA. Principles of PRA	2
10.	Operational guidelines for organizing PRA at village level. PRA and PLA – Concept, Methods, Tools, Interpretation and Techniques.	1
11.	Other relevant participatory approaches like RRA, PANR, etc. Emerging tools used for PRA (ICT, GIS, GPS, etc.)	1
	Total	18
	Practical	
1.	Visit to selected forest areas to undertake and understand various participatory research methods	8
2.	Including participatory rural appraisal techniques like social mapping, resource mapping, Venn diagrams, transect walk, time lines, etc.	8
	Total	**16**

I. Course Title : Management of Tree Insect Pests and Diseases

II. Course Code : FRM 511

III. Credit Hours : 2+1

IV. Aim of the course

To provide and understanding to the students on management of insect pests and diseases and aspects related to INM.

V. Theory

Unit I

Principles and methods of integrated pests management; Insect attractants and repellents; male sterility techniques.

Unit II

Important insect pests of nurseries, plantations, avenue trees and their management. Insect pests of seeds of forest trees and their management.

Unit III

Principles of tree disease. management; Integrated forest protection; development of disease management system.

Unit IV

Important diseases of nurseries, plantations and avenue trees and their management, Mycoflora of seeds and their management.

VI. Practical

- Collection and identification of insect pests and non-insect pests;
- Inspection and collection of insect damaged plant specimens;
- Preparations of different pesticides;
- Application of pesticides;
- Collection, preservation and identification of tree diseases, forest nursery and plantation;
- Isolation and characterization of tree pathogens;
- Preparation of fungicidal solutions; *In-vitro* efficacy and *In vivo* efficacy assessments.

VII. Suggested Reading

Agrios GN. 2005. *Plant Pathology*. Elsevier Acad. Press. Singapore.

Butin H. 1995. *Tree Diseases and Disorders*. Oxford Univ. Press, New York.

Evane JW. 1989. *Insect Pest and their Control*. Samir BooK Center, New Delhi (India).

Gonthia P and Nicolotti G. 2013. *Infectious Forest Diseases*. CABI, UK. Guy Watson., 2013, Tree Pests and Diseases.

Pathak H, Maru S, Satya HN and Silawat SC. 2015. *Fungal Diseases of Trees in Forest Nurseries of Indore, India.* J Plant Pathol Microb.

Sinclair W and Howard HL. 2005. *Diseases of Trees and Shrubs*.

Speight MR. 2000. *Insect Pest in Tropical Forestry*. Rose Willey Publications.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Concepts and terminologies in forest entomology	1
2.	Insect pest induced loss assessments in different forest nursery seedlings	2
3.	Insect pest induced loss assessments in different forest plantations	2
4.	Principles of integrated pest management	2
5.	Insect attractants and repellents, male sterility techniques	2
6.	Important insect pests of nurseries	1

Sr. No.	Topic	No. of Lecture(s)
7.	Important insect pests of plantation trees, avenue trees and their management	3
8.	Insect pests of seeds of forest trees and their management.	1
9.	Concepts and terminologies forest pathology	2
10.	Disease induced loss assessments in different forest nursery seedlings and plantations	2
11.	Principle methods of tree disease management	2
12.	Integrated forest protection	2
13.	Development of disease management system	2
14.	Important diseases of forest nurseries and their management	3
15.	Important diseases of forest plantations and avenue trees and their management	3
16.	Mycoflora of seeds and their management	2
	Total	32

Practical

1.	Collection and identification of insect pests and non-insect pests	2
2.	Inspection and collection of insect damaged plant specimens	3
3.	Preparations of different pesticides. Application of pesticides	3
4.	Collection, preservation and identification of tree diseases, forest nursery and plantation	3
5.	Isolation and characterization of tree pathogens	2
6.	Preparation of fungicidal solutions; *In-vitro* efficacy and *In vivo* efficacy assessments	3
	Total	**16**

I. Course Title : Forest Ecology, Biodiversity and Management

II. Course Code : FRM 512

III. Credit Hours : 2+1

IV. Aim of the course

This course would enable the students to understand the aspects related to forest ecosystem and its dynamics. As well it provides the knowledge on biodiversity conservation in natural forests and agro-ecosystems, policy issues, IPR, etc.

V. Theory

Unit I

Introduction to forest ecology, forest population, forest community dynamics, forest community structure and analysis, forest productivity on a global scale, ecology of forest landscapes spatial heterogeneity; Hierarchy issues in ecology.

Unit II

Biodiversity-an overview; genetic, species and ecosystem diversity; determinants of biodiversity. Higher plant diversity, species richness and endemism. Managing plant genetic resources: Basic science issues – genetic vulnerability and crop diversity, crop diversity-institutional responses, *in situ* conservation of genetic resources, the science of collecting genetic resources, the science of managing genetic resources, using genetic resources, biotechnology and germplasm conservation, etc.

Unit III

Complementary strategies for plant biodiversity conservation. *In situ* conservation of wild species in nature reserves, in situ conservation components, factors influencing conservation value, national plan for *in situ* conservation. In situ conservation of Forest and agro-biodiversity on-farm: importance of on-farm conservation initiatives, overview of the types of information necessary in the design of an on-farm conservation programme.

Unit IV

Managing plant genetic resources: policy issues (exchange of genetic resources: quarantine, IPR; genetic resources: assessing economic value; conflicts over ownership, management and use; national and international treaties/ legislations: CBD, IT-PGRFA, GPA, PVP and FR Act, Biodiversity Act, etc.). International instruments concerning agro-biodiversity, Agenda 21, convention on biological diversity (CBD), FAO and global system of PGR, the International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action, TRIPS agreement and IPR protection of life forms.

VI. Practical

- Study of forest community structure and its successional status;
- Estimation of productivity of forest ecosystem;
- Trip to different regions of the state to study forest vegetation, Collection and preservation of specimen;
- Methods of vegetation analysis, Measurement of biomass and productivity;
- Quantification of litter production and decomposition;
- Visit to national parks, wildlife sanctuaries, botanical gardens and arboreta.

VII. Suggested Reading

Bonneuil, Christophe and Jean-Baptiste F. *The Shock of the Anthropocene: The Earth, History and Us. London*; Brooklyn, NY: Verso, 2016. (Chapter 1: Welcome to the Anthropocene).

Brush SB. 1999. *Genes in the Field: On-farm Conservation of Crop Diversity*. Lewis Publishers, Boca Raton, Florida, USA.

Chandna RC. 2002: *Environmental Geography*, Kalyani, Ludhiana.

Cunninghum WP and Cunninghum MA. 2004: *Principles of Environmental Science: Inquiry and Applications*, Tata Macgraw Hill, New Delhi.

Engels JMM. 1995. *In Situ Conservation and Sustainable Use of Plant Genetic Resources For Food and Agriculture in Developing Countries*. IPGRI/ DSE.

Jarvis D, Staphit B and Sears L. 2000. *Conserving Agricultural Biodiversity in Situ: A Scientific Basis for Sustainable Agriculture*. IPGRI, Rome, Italy.

Maxted N, Ford-Lloyd BV and Hawkes JG. 1997. *Plant Genetic Conservation: The In Situ Approach*. Chapman & Hall, London.

Wood D and Lenne J. 1999. *Agrobiodiversity: Characterisation, Utilization and Management*. CAB International, Wallingford.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Introduction to forest ecology, forest population, forest community dynamics, forest community structure and analysis	2

Sr. No	Topic	No. of Practical(s)
2.	Forest productivity on a global scale, ecology of forest landscapes spatial heterogeneity; Hierarchy issues in ecology	2
3.	Biodiversity-an overview; genetic, species and ecosystem diversity; determinants of biodiversity. Higher plant diversity, species richness and endemism	2
4.	Managing plant genetic resources: Basic science issues – genetic vulnerability and crop diversity, crop diversity-institutional responses, in situ conservation of genetic resources	3
5.	The science of collecting genetic resources, the science of managing genetic resources, using genetic resources	2
6.	Biotechnology and germplasm conservation	1
7.	Complementary strategies for plant biodiversity conservation. In situ conservation of wild species in nature reserves, in situ conservation components, factors influencing conservation value, national plan for in situ conservation	4
8.	In situ conservation of Forest and agro-biodiversity on-farm: importance of on-farm conservation initiatives, overview of the types of information necessary in the design of an on-farm conservation programme	4
9.	Managing plant genetic resources: policy issues (exchange of genetic resources: quarantine, IPR; genetic resources: assessing economic value; conflicts over ownership, management and use	4
10.	National and international treaties/ legislations: CBD, IT-PGRFA, GPA, PVP and FR Act, Biodiversity Act, etc.)	4
11.	International instruments concerning agro-biodiversity, Agenda 21, convention on biological diversity (CBD), FAO and global system of PGR, the International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action, TRIPS agreement and IPR protection of life forms	4
	Total	32

Practical

1.	Study of forest community structure and its successional status	2
2.	Estimation of productivity of forest ecosystem	2
3.	Trip to different regions of the state to study forest vegetation, Collection and preservation of specimen	4
4.	Methods of vegetation analysis, Measurement of biomass and productivity	3
5.	Quantification of litter production and decomposition	2
6.	Visit to national parks, wildlife sanctuaries, botanical gardens and arboreta	3
	Total	**16**

Course Title with Credit Load
Ph.D. (Forestry) in Forest Resource Management

Course Code		Course Title	Credit Hours
	Major Courses		
FRM 601*	I	Forest Management	2+1
FRM 602	II	Forest Economic Analysis	2+1
FRM 603	I	Climate Change and Forestry	1+1
FRM 604	II	Geo-informatics in Natural Resource Management	2+1
FRM 605*	I	Environmental Impact Analysis and Assessment	2+1
FRM 606	II	Forest Soil Management	2+1
FRM 607	I	Environmental Modelling and Biostatistics	2+0
FRM 608	II	Approaches in Forest Resource Management	1+1
FRM 609	I	Forest Hydrology and Watershed Management	2+1
FRM 610	II	Operational Research in Forest Management	1+1
	Minor Courses		
	Courses from Silviculture and Agroforestry or Forest Biology and Tree Improvement or Forest Products and Utilization		06
	Supporting Courses		
FOR 610*	I	Research Methodology in Forestry	2+1
FOR 611	II	Research and Publication Ethics	1+1
FRM 691*	I/ II	Doctoral Seminar	1+0
FRM 692*	I/ II	Doctoral Seminar	1+0
	ii) Thesis Research		
FRM 699		Doctoral Research	0+75

*Compulsory Core Courses

Course Contents
Ph.D. (Forestry) in Forest Resource Management

I. Course Title : Forest Management

II. Course Code : FRM 601

III. Credit Hours : 2+1

IV. Aim of the course

To provide the recent knowledge on management of Indian forests, different methods of yield regulation in regular and irregular forests and forest evaluation and appraisal in regulated forests.

V. Theory

Unit I

Evolution of Indian forest management system and current approaches of forest management. Goal-Dimension matrix in forest management and its application to natural forest and plantations. Case studies in relation of even and uneven aged stands. Project planning, classical approaches to yield regulation in forest management,salient feature and strategies.

Unit II

Operational research methods in forest management and application; use of operational research methods in forest planning models; emphasis on algorithms, problem formulation and interpretation of results.

Unit III

Simulation modeling of forest operations processing facilities; principles and methodology for performing simulation experiments; emphasis on building, running and analyzing simulation based models applicable to forest operations and wood products processing. Application of programming-linear and dynamic, network analysis, PERT (program evaluation and review technique) and CPM (Critical path method), inventory models.

Unit IV

Working plans and working schemes, their role in nature conservation, biodiversity and other dimensions and control.

VI. Practical

- Application of above techniques through a case analysis using forest inventories;
- Application and use of operational research methods in forest planning models;
- Simulation modeling of forest operations and processing facilities.

VII. Suggested Reading

Arunachdam A and Kha ML 2001. *Sustainable Management of Forest in India*, IBD, Dehradun.

Bentley J and Recknagel AB. 1995. *Forest Management*. International book distributors, Dehra Dun.

Davis *et al*. 2005. *Forest Management*, IV Edition. Waveland Press Inc, USA.

Innes JL. 1993. *Forest Health-Its Assessment and Status*, CAB international, U.K.
Pulparambil J. 2002. *Forest Management – An HRD Approach*. Uppal Publishing House, New Delhi.
Raison RJ, Brown AJ and Flimn PW. 2003. *Criteria and Indicators for Sustainable Forest Management*. CAB Publications, UK.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Principles of forest management; scope and objectives of forest management, ecosystem management, development of forest management in India	3
2.	Case studies in relation of even and uneven aged stands. Project planning	3
3.	Site quality evaluation and importance. Stand density	2
4.	Classical approaches to yield regulation in forest management, salient feature and strategies, Basis of yield regulation. Methods of yield regulation. Examples in relation to Indian forests	5
5.	Forest evaluation and appraisal in regulated forests. Operational research methods in forest management and application	3
6.	Application of operational research methods in forest planning models; emphasis on algorithms, problem formulation and interpretation of results	3
7.	Simulation modeling of forest operations processing facilities; principles and methodology for performing simulation experiments; emphasis on building, running and analyzing simulation based models applicable to forest operations and wood products processing	4
8.	Application of programming-linear and dynamic, network analysis, PERT (program evaluation and review technique) and CPM (Critical path method), inventory models	3
9.	Working plans and working schemes, their role in nature conservation, biodiversity and other dimensions and control	3
10.	Preparation of working plan, different types of map, steps in working plan preparation. Difference between management plan, working plan, microplan	3
	Total	30
	Practical	
1.	Application of above techniques through a case analysis using forest inventories	5
2.	Application and use of operational research methods in forest planning models.	5
3.	Simulation modeling of forest operations and processing facilities.	6
	Total	16

I. Course Title : Forest Economic Analysis

II. Course Code : FRM 602

III. Credit Hours : 2+1

IV. Aim of the course

Is to provide different aspects forest economics, Issues and dynamics of domestic and international demand and supply of forestry products.

V. Theory

Unit I

Use of theoretical frameworks of consumer behavior, market equilibrium, efficiency of perfect and imperfect competition, game theory, and social welfare functions in decision making about optimization of forest resources; Issues and dynamics of domestic and international demand and supply of forestry products.

Unit II

Models of optimal resource use – Applications of dynamic programming and optimal control – Optimal management of forestry resources – Logistic growth – Maximum sustainable yield – Optimal harvest rule – Regulated and unregulated common property. Economics of Forest Resource – optimal harvesting of single rotation and multiple rotation forests.

Unit III

National income accounting – estimation and methods – Issues and methodologies in green accounting.

Unit IV

Valuation of forestry goods and services – Direct valuation methods – Indirect valuation methods. Environmental pollution as a case of common property management- Policy initiatives for improving the management of common property resources and environmental conservation. Environmental regulation and policies – market based instruments – economic instruments – pollution charges, taxes, tradable permits.

VI. Practical

- Efficiency of perfect and imperfect competition – consumer surplus analysis. Game theory – social welfare function;
- Derivation of the fundamental equation of renewable resources – Estimation of growth curves and stock dynamics for forestry resources. Simple two period problem of optimal resource use – optimal rotation;
- National income accounting – methods Environmental Resource Accounting – Green GDP;
- Direct valuation methods – Indirect valuation methods. Criteria for evaluating the environment related projects and review of Environmental impact Assessment (EIA) techniques;
- Practical considerations and comparison of instruments of environmental policy – pollution control methodologies.

VII. Suggested Reading

Tom Totenberg and Lynne Lewis. 2009. *Environmental and Natural Resource Economics* Pearson – Addision Wesley publication, 9th edition.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Use of theoretical frameworks of consumer behavior, market equilibrium, efficiency of perfect and imperfect competition	3
2.	Game theory, and social welfare functions in decision making about optimization of forest resources	3
3.	Issues and dynamics of domestic and international demand and supply of forestry products	3
4.	Models of optimal resource use – Applications of dynamic programming and optimal control – Optimal management of forestry resources – Logistic growth – Maximum sustainable yield – Optimal harvest rule	4
5.	Regulated and unregulated common property	2
6.	Economics of Forest Resource – optimal harvesting of single rotation and multiple rotation forests	3
7.	National income accounting – estimation and methods – Issues and methodologies in green accounting	3
8.	Valuation of forestry goods and services – Direct valuation methods – Indirect valuation methods	4
9.	Environmental pollution as a case of common property management-Policy initiatives for improving the management of common property resources and environmental conservation	3
10.	Environmental regulation and policies – market based instruments – economic instruments – pollution charges, taxes, tradable permits	4
	Total	32
	Practical	
1.	Efficiency of perfect and imperfect competition – consumer surplus analysis. Game theory – social welfare function	3
2.	Derivation of the fundamental equation of renewable resources – Estimation of growth curves and stock dynamics for forestry resources. Simple two period problem of optimal resource use – optimal rotation.	4
3.	National income accounting – methods Environmental Resource Accounting – Green GDP	2
4.	Direct valuation methods – Indirect valuation methods. Criteria for evaluating the environment related projects and review of Environmental impact Assessment (EIA) techniques	4
5.	Practical considerations and comparison of instruments of environmental policy – pollution control methodologies	3
	Total	16

I. Course Title : Climate Change and Forestry

II. Course Code : FRM 603

III. Credit Hours : 1+1

IV. Aim of the course

To develop an understanding among the students on the recent aspects of climate change, mitigation and adaptation options and the current national and international initiatives to tackle climate change.

V. Theory

Unit I

History of climate change, Institutional developments towards climate change. Recent developments in global climate changes: Changes in source and sinks of carbon in the last few decades. Global warming potentials of major GHG's.

Unit II

Effect of climate change on: Ocean, Soil, Forest, Biodiversity, Agriculture and Livelihood and relevant mitigation measures to address these issues. Climate change, Economic development and energy conservation dilemma. Role of alternate energy sources and its current status towards offsetting fossil fuel use. Carbon Footprint: concepts, methods of assessment, applications and its uses in different fields with special reference to Agriculture. Role of agroforestry strategies to increase terrestrial carbon sinks. Global dimming; role of aerosols in global dimming and implications to solar energy constant.

Unit III

Policy issues: Kyoto protocol, carbon trading mechanisms, Montreal agreement, Marrakesh Accord, REDD, REDD+ and other recent international agreements and negotiations to address the climate change issues. Other Climatic aberrations and its relationship to climate change: Ozone depletion, ENSO, etc. India's stand on climate change: Recent developments in the strategies; Green India Mission, CAMPA, Millennium goal and other policy initiatives to mitigate climate change.

VI. Practical

- Atmospheric CO_2 measurement methods;
- Soil Carbon assessment, Soil carbon dynamics;
- Atmospheric CO_2 flux measurements. Exposing plants to elevated CO_2 concentration.

  FACE and FATE experiments, Open top chambers and its importance in understanding the effect of increased CO_2 concentration and plant growth;
- Differential responses of species to elevated CO_2 concentrations. Diurnal plant response t light, temperature and CO_2 concentration.

VII. Suggested Reading

Houghton John. 2009. *Global Warming* (Fourth edition). Cambridge Press.

J Jager and HL Ferguson. 2007. IPCC Assessment Report. *Climate Change Journal Climate Change: Source, Impact and Policy*, Proceeding of 2nd World Climate Conference. Cambridge University Press, 1993.

Parry, Martin L, Canziani, Osvaldo F, Palutikof, Jean P, Van der Linden, Paul J and Hanson, Clair E. 2007. IPCC. Cambridge University Press, Cambridge, United Kingdom.

Reddy KR and Hodges HF. 2000. *Climate Change and Global Crop Productivity*. CABI Publishing.

Robert M, Clausen and Henry L Gholz. *Carbon and Forest Management*. School of Forest Resources and Conservation. University of Florida, Gainesville, FL 32611, USA.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	History of climate change, Institutional developments towards climate change	1
2.	Recent developments in global climate changes: Changes in source and sinks of carbon in the last few decades	1
3.	Global warming potentials of major GHG's	1
4.	Effect of climate change on: Ocean, Soil, Forest, Biodiversity, Agriculture and Livelihood and relevant mitigation measures to address these issues	2
5.	Climate change, Economic development and energy conservation dilemma. Role of alternate energy sources and its current status towards offsetting fossil fuel use	2
6.	Carbon Footprint: concepts, methods of assessment, applications and its uses in different fields with special reference to Agriculture. Role of agroforestry strategies to increase terrestrial carbon sinks	2
7.	Global dimming: role of aerosols in global dimming and implications to solar energy constant	2
8.	Policy issues: Kyoto protocol, carbon trading mechanisms, Montreal agreement, Marrakesh Accord, REDD, REDD+ and other recent international agreements and negotiations to address the climate change issues	2
9.	Other Climatic aberrations and its relationship to climate change: Ozone depletion, ENSO, etc.	2
10.	India's stand on climate change: Recent developments in the strategies; Green India Mission, CAMPA, Millennium goal and other policy initiatives to mitigate climate change	2
	Total	16
	Practical	
1.	Atmospheric CO_2 measurement methods	2
2.	Soil Carbon assessment, Soil carbon dynamics	3
3.	Atmospheric CO_2 flux measurements. Exposing plants to elevated CO_2 concentration	3
4.	FACE and FATE experiments, Open top chambers and its importance in understanding the effect of increased CO_2 concentration and plant growth	3
5.	Differential responses of species to elevated CO_2 concentrations. Diurnal plant response to light, temperature and CO_2 concentration	4
	Total	16

I. Course Title : Geo-informatics in Forest Resource Management

II. Course Code : FRM 604

III. Credit Hours : 2+1

IV. Aim of the course

Is to develop and understanding among the students on basics of geomatics and its application for sustainable management of natural resources.

V. Theory

Unit I

Brief introduction to Remote sensing and GIS, types of remote sensing, aerial photography, scale, process of aerial photography. Platforms, orbit and sensors, types of sensors: ground based, air borne and space borne; geostationary satellite and polar orbiting satellite.

Unit II

Data structure, type and model: Raster and Vector data structure, vector data type, point, line and polygon. Data hierarchical models and overlays. Spatial analysis of vector based and raster based data in the software. Digital elevation models, Global positioning system and differential GPS.

Unit III

Optical, thermal and microwave remote sensing, LiDAR remote sensing. Satellite image interpretation and recognisation elements: tone, color, texture, pattern, shape, size and associated features.Introduction of ERDAS, Arc GIS and PolSar-Pro, ENVI softwares, Digital image processing, image rectification, geometric corrections, Image enhancement techniques, Digital image classification, supervised and unsupervised classification.

Unit IV

Applications of Multispectral, Hyperspectral, thermal and microwave remote sensing. Case studies on application of remote sensing and GIS in natural resource management.

VI. Practical

- Spectral characteristics of vegetation, water and soil;
- Study of Topo-sheets, Forest watershed delineation using GPS, Satellite remote sensing;
- Study of satellite imageries; Digital image interpretation, Digital image processing in ERDAS software, image classification in ERDAS, preparation of thematic maps in Arc GIS, Watershed delineation and clipping using ERDAS and Arc GIS. Mapping of forest with PolSarPro software, Biomass estimation using RS techniques.

VII. Suggested Reading

Campbell JB. 2002. *Introduction to Remote Sensing*-Third edition. Taylor and Francis, London.

Environment System Research Institute.1999. *GIS for Everyone*. Redlands, CA:ESRI.

Jackson MJ. 1992. *Integrated Geographical Information Systems*. International Journal of Remote Sensing, 13(6-7): 1343-1351.

Joseph G. 2005. *Fundamentals of Remote Sensing*-Second edition. Universities Press.

Lillesand TM and Kiefer WR. 1994. *Remote Sensing and Image Interpretation*, Fourth edition. John Wiley & Sons, Inc., USA.

Obi Reddy, GP and Sarkar D. 2012. *RS and GIS in Digital Terrain Analysis and Soil Landscape Modelling*. NBSS & LUP, Nagpur.

Prithvish Nag. 1995. *Digital Remote Sensing*. IBD, Dehradun.

Surender Singh and Patel. 1999. *Principles of Remote Sensing*. Scientific Publishers, Jodhpur, India.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Brief introduction to Remote sensing and GIS, types of remote sensing, aerial photography, scale, process of aerial photography	3
2.	Platforms, orbit and sensors, types of sensors: ground based, air borne and space borne; geostationary satellite and polar orbiting satellite	3
3.	Data structure, type and model: Raster and Vector data structure, vector data type, point, line and polygon. Data hierarchical models and overlays	4
4.	Spatial analysis of vector based and raster based data in the software. Digital elevation models, Global positioning system and differential GPS	4
5.	Optical, thermal and microwave remote sensing, LiDAR remote sensing. Satellite image interpretation and recognisation elements: tone, color, texture, pattern, shape, size and associated features	4
6.	Introduction of ERDAS, Arc GIS and PolSar-Pro, ENVI softwares, Digital image processing, image rectification, geometric corrections, Image enhancement techniques, Digital image classification, supervised and unsupervised classification	6
7.	Applications of Multispectral, Hyperspectral, thermal and microwave remote sensing	4
8.	Case studies on application of remote sensing and GIS in natural resource management	4
	Total	32
	Practical	
1.	Spectral characteristics of vegetation, water and soil;	3
2.	Study of Topo-sheets, Forest watershed delineation using GPS, Satellite remote sensing	3
3.	Study of satellite imageries; Digital image interpretation, Digital image processing in ERDAS software, image classification in ERDAS	4
4.	Preparation of thematic maps in Arc GIS, Watershed delineation and clipping using ERDAS and Arc GIS	3
5.	Mapping of forest with PolSarPro software, Biomass estimation using RS techniques	3
	Total	16

I. Course Title : Environmental Impact Analysis and Assessment

II. Course Code : FRM 605

III. Credit Hours : 2+1

IV. Aim of the course

To impart the knowledge on nature and principles of EA; Procedure and monitoring of EA results; Developing, conducting and evaluating an EA. Report Writing; EIA/ EA Project Report; EIA/ EA Review and Decision Making Process; Environmental Management Plan.

V. Theory

Unit I

EIA Functions, development and environmental degradation. International and National Laws. EIA steps. Social Impact Analysis. The Convention on Environmental Impact Assessment in a local context – Objective and scope, Obligation to notify and consult, Public participation, Content of EIA documentation, Implementation and Compliance. Protocol on Strategic Environmental Assessment- Objective, Key provisions.

Unit II

Nature and principles of EA; Procedure and monitoring of EA results; Developing, conducting and evaluating an EA. Report Writing; EIA/ EA Project Report; EIA/ EA Review and Decision Making Process; Environmental Management Plan.

Unit III

Methods of EIA – Check Lists – Matrices – Networks – Cost-Benefit Analysis. Assessment of Impact on Land, Water, Air, Social and Cultural Activities and on Flora and Fauna- Mathematical Models- Public Participation.

Unit IV

Plan For Mitigation Of Adverse Impact On Environment – Options For Mitigation of Impact on Water, Air, Land And on Flora and Fauna – Addressing The Issues Related To The Project Affected People. Post Project Monitoring.

VI. Practical

- Environmental auditing – History of environmental auditing. Introduction to the types of environmental audit;
- Analyze proposed development project plans for possible environmental effects and prepare appropriate initial studies;
- Utilize EIA documents for policy development, project planning or for legal or political action planning.

VII. Suggested Reading

Anjanayulu Y. 2002. *EIA Methodlogies*. BSP BS publication.

Brady J. 2011. *The response of organizations*. In: Brady J, Ebbage A, Lunn R (eds.) *Environmental Management in Organizations: The IEMA Handbook*, 2nd edn. Earthscan, London, pp. 251–260.

Humphrey N and Hadley M. 2000. *Environmental Auditing*. Palladian Law Publishing Ltd,

Lawrence and Dravid P. 2003. *EIA Practical Solutions to Recrurrent Problems*.

Morgan RK. 1988. EIA- *A Methodological Perspective* Kluwer Academic Publishers.

Smith LG. 1993. *Impact Assessment and Sustainable Resource Management*. John Wiley & Sons. New York.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	EIA Functions, development and environmental degradation. International and National Laws. EIA steps. Social Impact Analysis	3
2.	The Convention on Environmental Impact Assessment in a local context – Objective and scope, Obligation to notify and consult,	

Sr. No	Topic	No. of Lecture(s)
	Public participation	3
3.	Content of EIA documentation, Implementation and Compliance. Protocol on Strategic Environmental Assessment- Objective, Key provisions	4
4.	Nature and principles of EA; Procedure and monitoring of EA results; Developing, conducting and evaluating an EA	4
5.	Report Writing; EIA/ EA Project Report; EIA/ EA Review and Decision Making Process; Environmental Management Plan	4
6.	Methods of EIA – Check Lists – Matrices – Networks – Cost-Benefit Analysis. Assessment of Impact on Land, Water, Air, Social and Cultural	4
7.	Activities and on Flora and Fauna- Mathematical Models- Public Participation	3
8.	Plan For Mitigation Of Adverse Impact On Environment	1
9.	Options For Mitigation of Impact on Water, Air, Land And on Flora and Fauna	3
10.	Addressing The Issues Related To The Project Affected People. Post Project Monitoring	3
	Total	32

Practical

1.	Environmental auditing – History of environmental auditing	4
2.	Introduction to the types of environmental audit	4
3.	Analyze proposed development project plans for possible environmental effects and prepare appropriate initial studies	4
4.	Utilize EIA documents for policy development, project planning or for legal or political action planning	4
	Total	16

I. Course Title : Forest Soil Management

II. Course Code : FRM 606

III. Credit Hours : 2+1

IV. Aim of the course

To acquire knowledge on advances in forest soil management. Hydrology of forest plantation. Stand development and soil productivity. Harvest removal and nutrient budgeting.

V. Theory

Unit I

Soils and their management for plantation forestry: Soils of the tropics, Soil requirements for plantation forestry, physical properties of major soils of India, soil erosion and erodibility, Erosion control.

Unit II

Dynamics of nutrient supply in plantation soils: variability of nutrient stores in forest soils, changes in nutrient content, nutrient losses and their assessment, nutrient gains, Nutrient transformation in soils. Nitrogen fixation in Tropical forest Plantations: N fixation process, species, rates of N fixation, factors influencing N fixation; Nutrient cycling – comparison of plantation productivity – case studies.

Unit III

Organic matter: Decomposition and mineralization; Litter accumulation, litter decomposition, effect of litter on soil, Interpretation of accumulation, decay and mineralisation processes, management of litter and soil organic matter in forest plantations. Soil and stand management for short rotation plantations; Water availability, Nutrient supply, uptake and tree growth, constraints on production, nutrient amendments and correction of nutrient deficiency.

Unit IV

Nutritional factors controlling stand growth. Reforestation of salt affected, acid soils and coastal soils. Effects of fire on soils: Types of fires, effects of fire on soil properties, effects of fire on air and water quality.

Unit V

Management and long term soil productivity – soil compaction and erosion – Harvest removal and nutrient Budgeting – Harvest effect on water quality – strategies for future management.

VI. Practical

- Nutrient budgeting for different plantation systems;
- Quantification of physical and chemical soil constraints in plantation and Agroforestry systems;
- Evolving new strategies for development.

VII. Suggested Reading

Binkley D and R Fisher 2012. *Ecology and Management of Forest Soils* (4th Edition), John Wiley & Sons Singapore Pte. Ltd., Singapore.

Brady NC and Weil RR. 2010. *Elements of the Nature and Properties of Soils* (3rd Edition.), Pearson Education, New Delhi.

Das DK. 2011. *Introductory Soil Science* (3rd Edition), Kalyani publisher, Ludhiana (India).

Gupta PK. 2009. *Soil, Plant, Water and Fertilizer Analysis* (2nd Edition), AGROBIOS, Jodhpur (India).

ISSS. 2002. *Fundamentals of Soil Science*. Indian Society of Soil Science, IARI, New Delhi.

J Benton and Jones Jr. 2012. *Plant Nutrition and Soil Fertility Manual* (2nd Edition), CRC Press, USA.

Jackson ML. 2012. *Soil Chemical Analysis: Advanced Course*, Scientific Publisher.

Jaiswal PC. 2006. *Soil, Plant and Water Analysis* (2nd Edition), Kalyani Publishers, Ludhiana.

Khan TO. 2013. *Forest Soils: Properties and Management,* Springer International Publishing, Switzerland.

Mengel *et al*. 2001 *Principles of Plant Nutrition* (5th Edition), Springer.

Pritchett and Fisher RF 1987. *Properties and Management of Forest Soils*. John Wiley, New York.

Reddy MV. 2001. *Management of Tropical Plantation Forests and Their Soil Litter System-Litter, Biota and Soil Nutrient Dynamics*, Science Publishers, U. S.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Soils and their management for plantation forestry: Soils of India	2
2.	Soil requirements for plantation forestry, physical properties of major soils of India, soil erosion and erodibility, erosion control	3
3.	Dynamics of nutrient supply in plantation soils: variability of nutrient stores in forest soils, changes in nutrient content	1
4.	Nutrient losses and their assessment, nutrient gains, nutrient transformation in soils	2
5.	Nitrogen fixation in tropical forest plantations: N fixation process, species, rates of N fixation, factors influencing N fixation	2
6.	Nutrient cycling – comparison of plantation productivity – case studies	2
7.	Hydrology of forest plantations: Forest hydrological cycle; The role of hydrological modelling in plantation management	2
8.	Organic matter: decomposition and mineralization; Litter accumulation and decomposition, effect of litter on soil, Interpretation of accumulation, decay and mineralisation processes	3
9.	Management of litter and soil organic matter in forest plantations	2
10.	Soil and stand management for short rotation plantations	1
11.	Water availability, Nutrient supply, uptake and tree growth, constraints on production, nutrient amendments and correction of nutrient deficiency	3
12.	Nutritional factors controlling stand growth	1
13.	Reforestation of salt affected and acid soils, coastal soils	2
14.	Effects of fire on soils: types of fires, effects of fire on soil properties, effects of fire on air and water quality	2
15.	Management and long term soil productivity – soil compaction and erosion	2
16.	Harvest removal and nutrient budgeting – harvest effect on water quality – strategies for future management	2
	Total	32
	Practical	
1.	Nutrient budgeting for different plantation systems	4
2.	Quantification of physical and chemical soil constraints in plantation and Agroforestry systems	6
3.	Evolving new strategies for development	6
	Total	16

I. Course Title : Environmental Modeling and Biostatistics

II. Course Code : FRM 607

III. Credit Hours : 2+0

IV. Aim of the course

To acquire knowledge on different environmental modeling approaches, sensitivity analysis and various statistical tools.

V. Theory

Unit I

Modeling for environmental sciences and management. Types of models. Causal diagrams, System Dynamics, Introduction to modelling software package, Population modelling, Modeling of material flows through the systems (pollutants transfer, etc). Modeling of cycles in nature (carbon cycle, etc.).

Unit II

Environmental modelling: scope and problem definition, goals and objectives, definition; modelling approaches – deterministic, stochastic and the physical approach; applications of environmental models; the model building process. Types of Model – Physical models, Conceptual models, Mathematical Models.

Unit III

Sensitivity analysis. Extinction risk. Multi-species population dynamics – Decision trees and Spatial models. Population Dynamics Predator-Prey (Lotka-Volterra methods) Model Builder in ArcGIS GIS Data for environmental models. GIS functions in environmental models. Model validation. Physical environmental models. Human (cultural, social, economic, etc.) environmental models.

Unit IV

Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing; Resampling techniques – Bootstrapping and Jack Knifing; Markov Models. Hidden Markov Models, Bayesian estimation and Gibbs sampling. Statistical fundamentals are reviewed and expanded upon with multi variable regression analysis of Variance (ANOVA).

VI. Suggested Reading

Clarke K *et al*. 2001. Geographic Information Systems and Environmental Modeling. Prentice Hall.

DeMers M. 2002. *GIS Modeling in Raster*. Wiley.

Goodchild *et al*. 1996. *GIS and Environmental Modeling: Progress and Research Issues*. GIS world, Inc.

Hooman R and Lukas KB. 2005. *Bioinformatics Basics: Applications in Biological Science And Medicine*. John Wiley.

Hooman Rashidi, Lukas K and Buehler. 2005. *Bioinformatics Basics: Applications in Biological Science and Medicine*. Taylor & Francis.

Maguire Batty and Goodchild. 2005. *GIS, Spatial Analysis, and Modeling*. ESRI Press.

Nirmal Khandan N. 2001. *Modelling Tools for Environmental Engineers and Scientists*, CRC Press, Boca Raton, Florida.

Rosner B. 2006. *Fundamentals of Biostatistics,* ed. 6,. Duxbury Press. USA.

Smith J and Smith P. 2007. *Introduction to Environmental Modelling*. Oxford: Oxford University Press.

Whitlock MC and Schluter D. 2009. *The Analysis of Biological Data*. Roberts and Company Publishers.

Zar JH. 2010. *Biostatistical Analysis*. 5th Edition. Pearson Education International.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Modeling for environmental sciences and management. Types of models. Causal diagrams, System Dynamics	3
2.	Introduction to modelling software package, Population modelling, Modeling of material flows through the systems (pollutants transfer, etc.). Modeling of cycles in nature (carbon cycle, etc.)	3
3.	Environmental modelling: scope and problem definition, goals and objectives, definition; modelling approaches– deterministic, stochastic and the physical approach	4
4.	Applications of environmental models; the model building process. Types of Model – Physical models, Conceptual models, Mathematical Models	3
5.	Sensitivity analysis. Extinction risk. Multi-species population dynamics- Decision trees and Spatial models	2
6.	Population Dynamics Predator-Prey (Lotka-Volterra methods) Model Builder in Arc GIS	2
7.	GIS Data for environmental models. GIS functions in environmental models	2
8.	Model validation. Physical environmental models. Human (cultural, social, economic, etc.) environmental models	2
9.	Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing	4
10.	Re-sampling techniques – Boot strapping and Jack Knifing; Markov Models. Hidden Markov Models, Bayesian estimation and Gibbs sampling. Statistical fundamentals are reviewed and expanded upon with multi variable regression analysis of Variance (ANOVA)	4
	Total	29

I. Course Title : Approaches in Forest Resource Assessment

II. Course Code : FRM 608

III. Credit Hours : 1+1

IV. Aim of the course

To inculcate knowledge and skills in students to employ participatory tools and techniques for effective planning, implementation, monitoring and evaluation of forestry projects, to efficiently carry out forest resource management and to effectively resolve conflicts by adopting participatory techniques.

V. Theory

Unit I

Participatory extension – Importance, key features, principles and process of participatory approaches; Different participatory approaches (RRA, PRA, PLA, AEA, PALM, PAR,PAME, ESRE, FPR) and successful models.

Unit II

Participatory tools and techniques. Space Related Methods: village map and village forest map (social and resource),mobility services and opportunities map and transect; Time related methods: time line, trend analysis, seasonal diagram. Daily activity schedule, dream map; Relation oriented methods:cause and effect diagram (problem tree), impact – diagram, well being ranking method, Venn diagram, matrix ranking, livelihood analysis after and before implementation of Watershed Programmes.

Unit III

Preparation of action plans, concept and action plan preparation; Participatory technology development and dissemination; Participatory planning and management, phases and steps in planning and implementation aspects; Process monitoring, participatory evaluation.

VI. Practical

- Visit to selected forest areas to undertake and understand various participatory research methods including participatory rural appraisal techniques like social mapping, resource mapping, Venn diagrams, transect walk, time lines, etc.

VII. Suggested Reading

Kothari CR. 1992. *Research Methodology- Methods and Techniques* Wiley Eastern Limited New Delhi.

Narayanasamy N. 2008. *Participatory Rural Appraisal: Principles, Methods and Application*.

Robert Chambers. 1981. "*Rapid Rural Appraisal" "Rationale and Repertoire*", IDS Discussion Paper, No. 155, IDS, Sussex.

Sabarathnam VE. 2002. *R/ R/ PRA for Agriculture.*Vamsaravath Publishers, Hyderabad.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Participatory extension – Importance, key features, principles and process of participatory approaches	2
2.	Different participatory approaches (RRA, PRA, PLA, AEA, PALM, PAR, PAME, ESRE, FPR) and successful models	2
3.	Participatory tools and techniques. Space Related Methods: village map and village forest map (social and resource), mobility services and opportunities map and transect	2
4.	Time related methods: time line, trend analysis, seasonal diagram. Daily activity schedule, dream map	2
5.	Relation oriented methods: cause and effect diagram (problem tree), impact – diagram, well being ranking method, Venn diagram, matrix ranking	2
6.	Livelihood analysis after and before implementation of Watershed Programmes	1
7.	Preparation of action plans, concept and action plan preparation	1
8.	Participatory technology development and dissemination	2
9.	Participatory planning and management, phases and steps in planning and implementation aspects; Process monitoring, participatory evaluation	2
	Total	16

Sr. No	Topic	No. of Practical(s)
	Practical	
1.	Visit to selected forest areas to undertake and understand various participatory research methods	8
2.	Including participatory rural appraisal techniques like social mapping, resource mapping, Venn diagrams, transect walk, time lines, etc.	8
	Total	16

I. Course Title : Forest Hydrology and Watershed Management

II. Course Code : FRM 609

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge and understanding among the students on various aspects of hydrology and watershed management and different government schemes on watershed management.

V. Theory

Unit I

Introduction to watershed hydrology, its management and agricultural sustainability issues; need of integrated watershed management in India; delineation of watersheds. Hydrology of watershed systems; estimation of surface runoff and sediment yields; effect of precipitation and hydro-climatic conditions on watershed systems; watershed erosion processes and their prevention; instrumentation and measurement of watershed management indicators.

Unit II

Use of GPS, GIS, RS and Decision Support Systems (DSS) in watershed management; technologies for rain-fed farming; socio-economic evaluation of the watershed management projects. Peoples' participation and livelihood analysis; cropping system and resource conservation techniques in watersheds.

Unit III

Heuristics and indigenous technical knowledge (ITKs) in watershed management; watershedassociations and groups in villages of India; Government policies, acts and schemes on watershed management

Unit IV

Mathematical modelling of hydrologic processes-precipitation, infiltration, evapo-transpiration, run-off, soil water balance. Watershed modeling. Frequency analysis for design of hydrologic systems; time series analysis for hydrologic design and forecasting.

VI. Practical

- Rain water budgeting – run off and soil loss, infiltration, soil moisture, deep percolation and ground water recharge, rainfall measurement hydrographs.
- Techniques for measuring subsurface flow on hill slopes. Field study of hill slope

flow processes.

- Survey of watershed, Preparation of micro-plan and planning of watershed for effective implementation.
- Preparation of contour maps, Estimation of earth work, Design of check dams, Acquaintance with water lifting devices, Use of measurement, Conveyance and control structures. Watershed delineation using GIS techniques.

VII. Suggested Reading

Chow VT, David M and Mays LW. 1988. *Applied Hydrology*. McGraw Hill.

Ghanshyan Das. 2000. *Hydrology and Soil Conservation Engineering*. Prentice Hall.

Isobel W Heathcote. 1998. *Integrated Watershed Management: Principles and Practice*. Wiley Publ.

Kenneth N Brooks, Peter FF folliott, Hans M Gregersen, Leonard F DeBano. 1991. *Hydrology and the Management of Watersheds*. Wiley-Blackwell.

Tideman EM. 1996. *Watershed Management*. Omega Scientific Publ.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Introduction to watershed hydrology, its management and agricultural sustainability issues; need of integrated watershed management in India; delineation of watersheds	4
2.	Hydrology of watershed systems; estimation of surface runoff and sediment yields	3
3.	Effect of precipitation and hydro-climatic conditions on watershed systems; watershed erosion processes and its prevention	3
4.	Instrumentation and measurement of watershed management indicators.	1
5.	Use of GPS, GIS, RS and Decision Support Systems (DSS) in watershed management; technologies for rain-fed farming; socio-economic evaluation of the watershed management projects	4
6.	Peoples' participation and livelihood analysis; cropping system and resource conservation techniques in watersheds	3
7.	Heuristics and indigenous technical knowledge (ITKs) in watershed management; watershedassociations and groups in villages of India	3
8.	Government policies, acts and schemes on watershed management	2
9.	Mathematical modelling of hydrologic processes-precipitation, infiltration, evapo-transpiration, run-off, soil water balance	3
10.	Watershed modeling	3
11.	Frequency analysis for design of hydrologic systems; time series analysis for hydrologic design and forecasting	3
	Total	32
	Practical	
1.	Rain water budgeting – run off and soil loss, infiltration, soil moisture, deep percolation and ground water recharge, rainfall measurements hydrograph	4
2.	Techniques for measuring subsurface flow on hill slopes. Field study of hill slope flow processes	3
3.	Survey of watershed, Preparation of micro-plan and planning of watershed for effective implementation	3

Sr. No	Topic	No. of Practical(s)
4.	Preparation of contour maps, Estimation of earth work, Design of check dams, Acquaintance with water lifting devices, Use of measurement, Conveyance and control structures	4
5.	Watershed delineation using GIS techniques	2
	Total	**16**

I. Course Title : Operational Research and Forest Modeling

II. Course Code : FRM 610

III. Credit Hours : 1+1

IV. Aim of the course

To provide different techniques and skills used in forest research, yield response models and their applications in forestry.

V. Theory

Unit I

Introduction to Operations Research-definitions- applications in forest science and management- Project Planning- Project Cycle-Project Evaluation tools-Log Frame Approach-Participatory Rural Appraisal – PERT -CPM- Advantages and Limitations, Application in Forestry Sector.

Unit II

Systems – Definitions – Components of a system – Modeling approach – Different kinds of models – their classification and properties – Simulation – Elements and basic concepts – Deterministic simulation – state variables, rate variables and drying variables – Feedback models and their solutions.

Unit III

Growth of biological populations – measurement of growth rate – population growth models – Discrete one species models – Exponential – Logistic – Gempertz and Mitcherlich– Richards Function Properties of models and estimation to biological data. Two species models – Predator and Prey models. 1569

Unit IV

Yield response models in single and multiple inputs – Quadratic – Square root – Estimating physical and Economic optimum Optimization of resources under constraints – Linear and non-linear programming – Formulation and their applications in Forestry.

VI. Practical

- Practicing Log Frame Approach(LFA-Participatory Rural Appraisal- PERT -CPM- Problems in Mathematical model – their classification and properties;
- Simulation – Examples – Growth Models – Linear – Exponential – Logistic – Richards – Gempertz and Mitcherlich – Predator and Prey models;
- Problems in Yield response models in single and multiple inputs – Quadratic – Square root –– Quadratic and square response models for several inputs – Estimating physical and Economic optimum;
- Formulation of L.P.P – Graphical method – Simplex method – Duality in L.P.P.

VII. Suggested Reading

Ranganathan CR. 2006. *A First Course in Mathematical Models of population Growth with MATLAB Programs*, Associated Publishing Company, New Delhi.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Introduction to Operations Research-definitions- applications i n forest science and management	1
2.	Project Planning- Project Cycle-Project Evaluation tools-Log Frame Approach-Participatory Rural Appraisal – PERT -CPM- Advantages and Limitations, Application in Forestry Sector	2
3.	Systems – Definitions – Components of a system – Modeling approach	1
4.	Different kinds of models – their classification and properties – Simulation – Elements and basic concepts – Deterministic simulation – state variables, rate variables and drying variables – Feedback models and their solutions	3
5.	Growth of biological populations – measurement of growth rate – population growth models	2
6.	Discrete one species models – Exponential – Logistic – Gempertz and Mitcherlich– Richards Function Properties of models and estimation to biological data	2
7.	Two species models – Predator and Prey models	1
8.	Yield response models in single and multiple inputs	1
9.	Quadratic – Square root –Estimating physical and Economic optimum Optimization of resources under constraints	2
10.	Linear and non-linear programming – Formulation and their applications in Forestry	1
	Total	16
	Practical	
1.	Practicing Log Frame Approach(LFA-Participatory Rural Appraisal- PERT -CPM- Problems in Mathematical model – their classification and properties	6
2.	Simulation – Examples – Growth Models – Linear – Exponential – Logistic – Richards – Gempertz and Mitcherlich – Predator and Prey models	4
3.	Problems in Yield response models in single and multiple inputs – Quadratic – Square root –– Quadratic and square response models for several inputs – Estimating physical and Economic optimum	4
4.	Formulation of L.P.P – Graphical method – Simplex method – Duality in L.P.P.	3
	Total	16

Supporting Courses (Compulsory at M.Sc. level)

I. Course Title : General Statistical Methods and Computer Applications

II. Course Code : FOR 511

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students who do not have sufficient background of statistical methods. The students would be exposed to concepts of general statistical methods and statistical inference that would help them in understanding the importance of statistical methodology. It would also help them in understanding the concepts involved in data presentation, analysis and interpretation of results.

V. Theory

Unit I

Review of probability. Random variable and mathematical expectation. Discrete and continuous probability distributions, viz., Binomial, Poisson and Normal distributions.

Unit II

Correlation and regression, Rank correlation, Non-linear regression, Partial and multiple correlation coefficient, Intra class correlation,Multiple linear regression.

Unit III

Introduction to theory of estimation, Testing of statistical hypothesis: chi-square, t and F distributions. Tests of significance based on chi-square, t and F tests. Large sample tests, Fisher Z transformation.

Unit IV

Analysis of variance: One way and two way classification. Design of Experiments: Basic Principles of design of experiments, Completely Randomised Design, Randomised Block Design, Latin Square Design. Elementary idea of factorial experiments. Estimation of genetic parameters from ANOVA table.

Unit V

Non-parametric tests: Sign test, Wilcoxon test, Mann-Whitney U-test, Wald Wolfowitz run test, Median test, Kruskal- Wallis test. MS Excel, Introduction to computer softwares.

VI. Practical

- Random variable and mathematical expectation;
- Fitting of distributions, viz., Binomial, Poisson, Normal;
- Correlation and regression;
- Non-linear regression;

- Multiple linear regression;
- Testing of hypothesis based on chi square, t and F tests. Large sample tests. Completely Randomised Design, Randomised Block Design, Latin Square Design and Factorial experiments. Non-parametric tests. Exercises based on computer software.

VII. Suggested Reading

Aggarwal BL. 1996. *Basic Statistics*. Wiley Eastern Limited, New Age International Ltd.

Bansal ML, Singh S, Singh TP and Kumar R. 2004. *Statistical Methods for Research Workers*. Kalyani Publishers.

Chandel SRS. 2014. *A Handbook of Agricultural Statistics*. Achal Prakashan.

Goon AM, Gupta MK and Dasgupta B. 1968. *Fundamentals of Statistics*, vol I, II. The World Press, Calcutta.

Snedecor GW and Cochran WG. 1980. *Statistical Methods*. East West Press.

Lecture Schedule

Sr. No.	Topic	No. of Lecture(s)
	Theory	
1.	Review of probability. Addition and multiplication law of probability	2
2.	Random variable and mathematical expectation	1
3.	Discrete and continuous probability distributions: Binomial, Poisson and Normal distributions	4
4.	Correlation and regression. Rank correlation	2
5.	Non-linear regression	1
6.	Partial correlation coefficient, multiple correlation coefficient, Multiple linear regression. Intra class correlation	4
7.	Introduction to theory of estimation	1
8.	Testing of statistical hypothesis: chi-square, t and F distributions. Tests of significance based on chi-square, t and F tests. Large sample test. Fisher z transformation	5
9.	Analysis of variance: One way and two way classification	2
10.	Design of Experiments: Basic Principles of design of experiments, Completely randomised design, Randomised block design, Latin square design	4
11.	Elementary idea of Factorial experiments. Estimation of genetic parameters from ANOVA table	3
12.	Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Wald Wolfowitz run test, Median test, Kruskal- Wallis test	2
13.	MS Excel, Introduction to computer software	2
	Total	**33**
	Practical	
1.	Random variable and mathematical expectation	1
2.	Discrete and continuous probability distributions: Binomial, Poisson and Normal distributions	2
3.	Correlation and regression. Rank correlation	1
4.	Non-linear regression	1
5.	Multiple linear regression. Intra class correlation	2
6.	Tests based on chi-square, t and F tests. Large sample test	2
7.	Analysis of variance: One way and two way classification	1

Sr. No	Topic	No. of Practical(s)
8.	Design of Experiments: Basic Principles of design of experiments, Completely randomised design, Randomised block design, Latin square design	2
9.	Elementary idea of Factorial experiments. Estimation of genetic parameters from ANOVA table	1
10.	Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Wald Wolfowitz run test, Median test, Kruskal- Wallis test.	1
11.	MS Excel, Applications of computer software to statistical analysis	2
	Total	**16**

Supporting Courses (Compulsory at Ph.D. level)

I. Course Title : Research Methodology in Forestry

II. Course Code : FOR 610

III. Credit Hours : 2+1

IV. Aim of the course

The students would exposed to concepts of design of experiments so as to enable them to understand the concepts involved in planning, designing their experiments and analysis of experimental/ field data. The students would also be exposed to elementary sampling techniques. It would help them in understanding the concepts involved in planning and designing their surveys, presentation of survey data, analysis of survey data and presemntation of results.

V. Theory

Unit I

Experimental Design: Research problem. Types of Research. Need for designing of experiments, Basic principles of design of experiment. Uniformity trials, size and shape of plots and blocks; Analysis of variance, Completely Randomized Design, Randomized Block Design and Latin Square Design. Factorial experiments, (symmetrical as well as asymmetrical). Confounding in symmetrical factorial experiments, Factorial experiments with control treatment. Split plot and strip plot designs; Analysis of covariance and missing plot techniques. Balanced incomplete block design, Fitting of response surfaces. Transformations of data. Groups of experiments.

Unit II

Sampling Theory: Basic terms used in sampling. Simple random sampling, Stratified random sampling, Systematic random sampling. Elementary idea of probability proportional to size, multistage, cluster and inverse sampling.

Unit III

Elementary idea to multivariate analytical tools- Classification and Discriminant function. Factor analysis, Principal component and cluster analysis.

VI Practical

- Analysis of data obtained from CRD, RBD, LSD;
- Analysis of factorial experiments without and with confounding;
- Analysis with missing data;
- Split plot and strip plot designs;
- Transformation of data; Fitting of response surfaces. Balanced incomplete block design;
- Groups of experiments. Simple random sampling, Stratified random sampling, Systematic random sampling.

VII Suggested Reading

Aggarwal BL. 2011. *Theory and Analysis of Experimental Designs*. CBS Publisher, New Delhi.
Gomez KA and Gomez AA. 1984. *Statistical Procedure for Agricultural Research*. John Wiley and Sons.
Johnson Richard A and Dean W Wichern. 2015. *Applied Multivariate Statistical Analysis*. Prentice Hall of India.
Mukopadhyay Parimal. 2008. *Theory and Methods of Survey Sampling*. Prentice Hall of India.
Sahu PK and Das AK.2014. *Agriculture and Applied Statistics* 2. Kalyani Publisher.
Singh D and Chaudhary FS. 2018. *Theory and Analysis of Sample Survey Design*. New Age International Ltd.
Zar Jerrold H. 2010. *Biostatistical Analysis*. Prentice Hall.

Lecture Schedule

Sr. No.	Topic	No. of Lecture (s)
	Theory	
1.	Need for designing of experiments, Basic principles of design of experiment. Uniformity trials, size and shape of plots and blocks	3
2.	Analysis of variance, Completely Randomized Design, Randomized Block Design and Latin Square Design	4
3.	Factorial experiments, Confounding in symmetrical factorial experiments	4
4.	Factorial experiments with control treatment	1
5.	Split plot and strip plot designs	3
6.	Analysis of covariance and missing plot techniques	2
7.	Balanced incomplete block design, Fitting of response surfaces. Transformations of dat	3
8.	Groups of experiments	2
9.	Basic terms used in sampling. Simple random sampling	3
10.	Stratified random sampling, Systematic random sampling	3
11.	Elementary idea of multistage, cluster and inverse sampling	2
12.	Elementary idea to multivariate analytical tools- Classification and Discriminant function. Factor analysis, Principal component and cluster analysis	2
	Total	**32**
	Practical	
1.	Analysis of variance, Completely Randomized Design, Randomized Block Design and Latin Square Design	3
2.	Factorial experiments, Confounding in symmetrical factorial experiments	3
3.	Factorial experiments with control treatment	1
4.	Split plot and strip plot designs	2
5.	Analysis of covariance and missing plot techniques	2
6.	Balanced incomplete block design, Fitting of response surfaces. Transformations of data	2
7.	Groups of experiments	1
8.	Simple random sampling, Stratified random sampling, Systematic random sampling	2
	Total	**16**

ANNEXURE I

List of BSMA Committee Members for Forestry

S.No.	Name and Address	Specialization
1.	**Dr L K Dashora** **Former Dean and ICAR Professor Emeritus** Agriculture University, Borkhera, Baran Road, Kota, Rajasthan/ R 5/51 Jaishri Colony, Dhulkot Road Udaipur-313 001 E-Mail: dashoralk_3303yahoo.com Mob: 09414285066	**Chairman**
2.	**Dr P K Mahajan** **Dean** College of Forestry, Dr YS Parmar Univ. of Horticulture and Forestry, Solan E-Mail: dean_cof@yahoo.co.in, deancof@yspuniversity.ac.in pawan_cof@yahoo.com Mob: 09418323933	**Convener**
3.	**Dr Dinesh Kumar** **Scientist G** Silviculture and Forest Management Division, Forest Research Institute Dehradun E-Mail: kumard@icfre.org Mob: 09411173576	**Member**
4.	**Dr Sushil Kumar Gupta** **Dean** College of Forestry, Ranichauri P.O. Ranichauri, Distt. Tehri Garhwal-249 199, Uttarakhand, India Phone: +91-1376-252080 (O), Fax: +91-1376-252128 E-mail: deanranichauri2013@gmail.com, sushilgupta67@rediffmail.com, Mobile: 09419109864	**Member**
5.	**Dr R.S Dhillon** **Professor and Head** Department of Forestry, College of Agriculture, Chaudhary Charan Singh Haryana Agriculture University, Hisar E-Mail: rsdhillon67@gmail.com, Mob: 09416343281	**Member**

S.No.	Name and Address	Specialization
6.	**Dr Sanjeev Thakur** **Professor and Head** Department of Tree Improvement and Genetic Resources, College of Forestry, Dr YS Parmar University of Horticulture and Forestry Nauni-Solan-173230 E-Mail: sanjeevtigr@yspuniversity.ac.in Mob: 09418150975	**Member**
7.	**Dr S S Narkhede** **Dean (Agri.) and Director of Instruction,** College of Forestry, Dr Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, District Ratnagiri-415712 E-Mail: ssn_forest@rediffmail.com Mob: 09422863027	**Member**
8.	**Dr P O Nameer** **Professor and Head** Department of Wildlife Sciences, College of Forestry, Kerala Agricultural University-680656, Thrissur E-Mail: nameer.po@kau.in Mob: 09446573106	**Member**
9.	**Dr Kulwant Rai Sharma** **Professor and Head** Department of Forest Products, College of Forestry, Dr YS Parmar University of Horticulture and Forestry, Solan-173230 E-Mail krai1960@yahoo.com, Mob: 09418230268	**Member**
10.	**Dr Bhupender Dutt** **Professor** Department of Forest Products, College of Forestry, Dr YS Parmar University of Horticulture and Forestry, Solan-173230 E-Mail: bdbfp@yahoo.co.in Mob.: 0821913706	**Member**

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Sericulture

Contents

Acknowledgements

Dr P. Venkataramana, Dean (Seri), College of Sericulture, Chintamani and Chairman of the BSMA committee on Sericulture and Dr V. Shankaranarayana, Former Dean (Seri), College of Sericulture, Chintamani and Convenor of the BSMA committee on Sericulture immensely acknowledges the Indian Council of Agricultureal Research, New Delhi for providing an opportunity to revise the post graduate programme syllabi in Sericulture offered in different State Agricultural universities of the country. The revision was done keeping in mind the recent advances in the field of sericulture in the country, abroad, farmers and industry. We hope, the revised syllabi will be of great help in catering the requirements of the above clients.

Dr P.Venkataramana
Dr V. Shankaranarayana

Preamble

Salient feature of revised syllabi and major changes made including new courses/ topics/ aspects added

- M.Sc. (Agri.) in sericulture courses for majority of the courses the title has been modified and syllabi is upgraded based on the recent advances in that particular course/ field.
- In the Genetics and Breeding of Mulberry course the recent technologies such as nano technology is included.
- The pests and diseases of both silkworms and host plant have been split into two courses separately for silkworms and mulberry.
- The silkworm seed and cocoon production the course have also separated into two courses, viz., silkworm egg production technology and silkworm rearing technology including the seed act 2010 by increasing one more credit hour.
- In the course silk technology it has been split into two courses *i.e*, Silk Technology-I for (M.Sc.) and silk technology-II for (Ph.D.) which covers the advanced technologies.
- In the course Non-mulberry sericulture the contents and syllabus is upgraded with more practical orientation including proteomics, transcriptomics and genomics organism.
- In the minor courses, viz., nutrition of host plant of silkworms recent topics on fertilizer use efficiency, enumeration of soil micro flora, trenching and mulching techniques in mulberry have been included.
- The biotechnological aspects of silkworms a mulberry dealt separately with more emphasis on practical aspects.
- In the sericulture by product utilization and value addition more emphasis has been laid on recycling of flimsy/ waste cocoons, use of seri proteins, etc.

Ph.D. (Agri.) in Sericulture

- The course title and syllabi of most of the courses modified keeping the recent advances in the courses in mind.
- The conventional, non-conventional methods of breeding, evaluation of germplasm for different stresses and recent breeding techniques applicable to mulberry have been included.
- The new topics an aeroponics and hydroponics are included.
- In the integrated pest management in sericulture course, the new topics such as taxonomy of protozoan and fungal species and different dis-infectetants used have also been covered.
- In the minor courses the silk technology-II is added to deal with new topics such as species and type concepts and recent preservation techniques.
- In the seri business management course the credit hours increased with more practical components and visit to seri business units/ centre/ institution/ NGO's, tasar and muga reeling technology, silk testing and grading, SERM and ARM, non-mulberry silk reeling technology, etc.

Aspects included in line with the national initiatives:

- Detailed study of silkworm and mulberry pests and diseases
- Seed act 2010
- Advanced silk technological aspects
- Fertilizer use efficiency.
- Trenching and mulching technique in mulberry
- Seri by product utilization, value addition
- Poly cross breeding in mulberry
- Histopathology of viruses, protozoans
- Entrepreneurship development in sericulture
- Silk preservation techniques
- Non mulberry silk reeling technology.

Topics covered related to global development:

- Nano technology
- Soil microflora
- Hydroponic and aeroponics
- Genomics, proteomics and transcriptomics
- Seri protein usage

The following nomenclature and Credit Hrs has been followed while providing the syllabus.

	Masters' Programme	Doctoral Programme
(i) Course work		
Major courses	20	12
Minor courses	08	06
Supporting courses	06	05
Common courses	05	–
Seminar	01	02
(ii) Thesis Research	30	75
Total	70	100

Course Title with Credit Load
M.Sc. (Agri.) in Sericulture

Course Code	Course Title	Credit Hours
	Major courses	
SER 501	Mulberry Production Technology	1+1
SER 502	Genetics and Breeding of Mulberry	1+1
SER 506	Systematics and Morphology of Sericigenous insects	1+1
SER 509	Silkworm Egg Production Technology	1+1
SER 510	Silkworm Rearing Technology	1+1
SER 511	Genetics and Breeding of Silkworms	1+1
SER 512	Diseases and Pests of Silkworms	1+1
SER 514	Silk Technology-I	1+1
SER 515	Non-mulberry Sericulture	1+1
	Principles of Biochemistry	1+1
	Design and Analysis of Experiments	1+1
	Scientific/ Technical writing Skills	1+1
	Research Methodology	1+1
		13+13=26
	Minor courses*	
SER 503	Nutrition of Host Plants of Silkworms	1+1
SER 504	Mulberry Pests and Diseases	2+1
SER 505	Biotechnology of Mulberry	1+1
SER 507	Anatomy and Physiology of Sericigenous insects	1+1
SER 508	Silkworm Biochemistry and Nutrition	1+1
SER 513	Biotechnology of Silkworm	1+1
SER 516	Sericulture By-product utilization and Value addition	1+1
		8+7=15

*Note: The students may opt the optional courses from any disciplines/ departments as recommended by the advisory committee of the student based on the research topic.

Major Courses Contents
M.Sc. (Agri.) in Sericulture

I. Course Title : Mulberry Production Technology

II. Course Code : SER 501

III. Credit Hours : 1+1

IV. Why this course ?

Mulberry is a perennial deep-rooted high biomass producing foliage crop, cultivated as a sole food for silkworm (*Bombyx mori* L). Mulberry cultivation is the very foundation of commercial sericulture to raise a successful cocoon crop. The quantity of leaf produced and its quality has a direct bearing on silkworm health and the quantity of cocoons produced. Thus, the profitability of sericulture and quality of cocoons depends on nutritive quality of mulberry leaves, as nearly as 70% of the silk proteins produced by the silkworm are directly derived from the mulberry leaves in addition to other nutrients. Hence, cultivation and best yield of the mulberry plants occupy important place in sericulture.

V. Aim of the course

The course is designed to provide both theory and practical knowledge on scope of mulberry sericulture, global distribution and factors influencing mulberry leaf yield and quality. Mulberry varieties, selection of site for garden, propagation techniques, soil and climatic requirements will be taught. Package of practices for raising mulberry saplings, rainfed and irrigated mulberry cultivation, separate chawki garden, tree mulberry, mulberry cultivation in hilly areas, intercropping, organic farming and IFS component will be part of the course. Use of growth hormones and growth regulators on mulberry leaf yield and quality will be studied in addition to pests and diseases of mulberry. Mulberry farm management and economics of mulberry production will e added.

The course is organized as follows:

No	Blocks	Units
1	Introduction, scope and varieties	I. Overview and scope of mulberry sericulture II. Varieties of mulberry
2	Mulberry production	I. Raising of mulberry saplings and planting. II. Establishment of mulberry garden
3	Mulberry protection	I. Mulberry pests and their management II. Mulberry diseases and their management
4	Economics	I. Economic of mulberry production

VI. Theory

BLOCK 1: Introduction, scope and varieties

Unit I: Overview and Scope of mulberry sericulture

Scope of mulberry sericulture, an overview of sericulture industry in the world and India. Leaf quality requirements, factors influencing mulberry leaf yield and quality. Scope for mechanization in mulberry cultivation.

Unit II: Varieties of mulberry

Mulberry varieties, Traditional mulberry varieties, popular mulberry varieties in different climatic zones, high yielding varieties, varieties for rainfed condition, varieties for specific conditions.

BLOCK 2: Mulberry production

Unit I: Raising of mulberry saplings and planting

Technology for raising of saplings for bush and tree type mulberry cultivation. Preparation of bed, planting material, transportation, storage, planting, weeding, fertilizer application and disease and pest management, uprooting, transportation and planting in main field.

Unit II: **Establishment of mulberry garden**

Package of practices for rainfed and irrigated mulberry cultivation, separate chawki garden, tree mulberry, mulberry cultivation in hilly areas. Selection of land, land preparation, planting, initial care and maintenance for different methods of mulberry cultivation and pruning practices. Mechanization in mulberry cultivation, intercropping, organic farming and IFS component. Manure and fertilizer schedule, irrigation schedule, use of biofertilizers for enhanced yield, use of growth hormones and growth regulators.

BLOCK 3: Mulberry protection

Unit I: Mulberry pests and their management

Mulberry pest status, occurrence, type of damage, symptoms, crop loss, life-cycle, different methods of management techniques, Integrated Pest Management (IPM) in mulberry.

Unit II: Mulberry diseases and their management

Mulberry diseases, occurrence, damage, symptoms, crop loss and different methods of management techniques and Integrated Disease Management (IDM) in mulberry.

BLOCK 4: Economics

Unit I: Economic of mulberry production

Farm records, role of non-monetary inputs in mulberry production, effective farm management, economics of mulberry production.

VII. Practicals

- Analysis of area, production and productivity of mulberry and sericulture in Karnataka, India and world;
- Study of Agronomic features of different mulberry varieties;
- Practising of different mulberry planting systems;
- Study of rooting and sprouting behaviour of mulberry varieties;
- Raising saplings through soft, semi soft and apical tender shoots;

- Mulberry nursery establishment and management;
- Study of mulberry as an intercrop in plantations;
- Selection of fruits and preparation of mulberry seeds for raising mulberry seedlings;
- Study of different planting systems of tree mulberry;
- Study of Intercropping in mulberry garden;
- Study of organic mulberry farming;
- Study of Mulberry as IFS component;
- Effect of different pruning systems on mulberry yield;
- Estimation of leaf area by non-destructive and destructive methods;
- Study of different leaf preservation techniques and different methods of leaf harvest with special reference to chawki and grown up silkworms;
- Study of different schedules of operation in mulberry garden and fertilizer application, methods of application and irrigation schedules;
- Study of weed flora in mulberry garden;
- Study of Farm records and Economics of mulberry cultivation;
- Institutional/ Farmers field visits.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the scientific foundation of mulberry cultivation and relate the key learning to both research and extension
- Utilise methods and tools for mulberry nursery and mulberry production
- Utilise material in scientific publications relevant to mulberry production technology and adoption that critically reflect on their benefits.

X. Suggested Reading

Anonymous. 1975. *Textbook of Tropical Sericulture.* Japan Overseas Co-operation volunteers, Japan, p.594.

Aruga H. 1994. *Principles of Sericulture*. Oxford & IBH, New Delhi, p. 376.

Dandin SB, Jaiswal and Giridhar. 2003. *Handbook of Sericulture Technologies.* CSB, Bangalore, p.287.

Ganga G and Sulochana Chetty J. 1991. *An Introduction to Sericulture*. Oxford & IBH, New Delhi, p.176.

Ganga G 2003. *Comprehensive Sericulture.* Volume 2. *Silkworm Rearing and Silk Reeling.* Oxford & IBH, New Delhi, p.429.

Govindaiah, Gupta VP, Sharma DD, Rajadurai S and Nishitha Naik V. 2005. *Textbook on Mulberry Crop Protection,* p 247.

Jolly MS. 1987. *Appropriate Sericulture Techniques.* Central Sericultural Research and Training Institute, CSB, Mysore, p.215.

Kamal Jaiswal, Sunil P Trivedi, Pandey, BN and Khatri RK. 2009. *Moriculture,* pp. 130-147.

Kichisaburo Minamizawa. 1984. *Moriculture: Science of Mulberry Cultivation,* pp. 372-402.

Rangaswamy G, Narasimhanna MN, Kasiviswanathan K, Sastry CR and Jolly M. 1976. *Manual on Sericulture-I.Mulberry Cultivation*, FAO, Rome, P.150.
Savithri G, Sujathamma P and Neeraja P. 2016. *Sericulture industry: an overview,* pp. 28-35.
Ullal, S.R. and Narasimhanna, M.N. 1981. *Handbook of Practical Sericulture,* CSB, P.209.

Journals

- *Bulletin of Indian Academy of Sericulture*, CSTRI, Berhampore
- *Indian silk,* CSB, Bangalore
- *Journal of Sericultural Science of Japan,* Japan
- *Seridoc*, CSRTI (CSB), Mysore
- *Sericologia*, ISC, Bangalore
- *Korean Journal of Sericulture*, Korea
- *Indian Journal of Sericulture*, CSRTI (CSB), Mysore
- And other Periodicals, Journals, Reports, Brochures, etc.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Genetics and Breeding of Mulberry

II. Course code : SER 502

III. Credit Hours : 1+1

IV. Why this course ?

Mulberry is perennial and highly heterozygous crop. In order to develop high yielding mulberry varieties for different situations, genetic principles and different breeding methods are prerequisite. In order to improve mulberry genetically, knowledge on different aspects of origin and diversity, floral structure, biology and pollination, genetic basis and concept of breeding, use of germplasm and conventional methods and non-conventional methods of breeding is essential. Hence this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of mulberry origin and diversity, floral structure, biology and pollination, genetic basis and general concept of breeding. Establishment of germplasm and genetic improvement of mulberry by conventional and non-conventional methods of breeding are dealt.

The course is organised as follows:

No.	Blocks	Units
1.	Taxonomy and botanical description and classification of mulberry	I Origin and diversity studies of mulberry
		II Study of floral structure, biology and pollination
		III Genetic basis and general concept of mulberry breeding
2.	Mulberry germplasm and breeding methods	I Mulberry germplasm
		II Conventional methods of breeding
		III Non-conventional methods of breeding

VI. Theory

BLOCK 1: Taxonomy and botanical description and classification of mulberry

Unit 1: Origin and diversity studies of mulberry

Centre of origin and diversity studies of mulberry, Mulberry species and their distribution in India and other countries. Taxonomy of the genus *Morus*. Botanical description of the *Morus* spp.

Unit 2: Study of floral structure, biology and pollination

Reproduction and genetic constitutions in mulberry –asexual reproduction- characteristics of mulberry florets- sexual behaviour-anthesis-reproductive variability. Pollination in mulberry. Cytology of mulberry, cell division- mitosis and meiosis and their significance. Karyomorphological studies. Microsporogenesis and Megasporogenesis in mulberry. Embryological studies of mulberry.

Unit 3: Genetic basis and general concept of mulberry breeding

Expression of gene: Segregation of genes, linkage, homozygosis, quantitative inheritance, features of polygenic inheritance, population structure, Selection of Parents for Hybridization. Procedure of Hybridization:Pruning and Synchronization of Flowering, Bagging, Tagging, Pollination. Harvesting and storing of F_1 seeds, Raising F_1 generation. Seedling Selection criteria. Difficulties in hybridization, Consequences of hybridization. Combining ability: general combining ability and specific combining ability, Heritability, genetic advance and genetic divergence.

BLOCK 2: Mulberry germplasm andbreeding methods

Unit 1: Mulberry germplasm

Establishment of mulberry,objectives and need, exploration, collection and introduction of mulberry germplasm, acclimatization and utilization. Introductions, world collection of mulberry germplasm, plant quarantine, conservation and maintenance of mulberry germplasm, characterization and evaluation of mulberry germplasm, role of mulberry germplasm study in mulberry improvement.

Unit 2: Conventional methods of breeding

Objectives and pre-requisites of mulberry breeding. Genetics of important traits. Early works of mulberry breeding, problems associated with mulberry breeding, conditions favouring mulberry breeding. Reproductive systems and plant breeding methods, Pollination in mulberry and crossing techniques. Mulberry varieties developed through direct selection, selection without controlled pollination, controlled pollination methods, handling of segregating progenies, Conventional methods of breeding- introduction, clonal selection, backcross method. Intervarietal and distant hybridization. Heterosis breeding. Population improvement. Polycross hybrids – Principles involved, advantages and disadvantages, steps in development of polycross hybrids. Multilocational trial and mulberry authorization programme, testing of feed quality. Advanced generation breeding. Improved varietal evaluation distribution and maintenance. Challenges for future.

Unit 3: Non-conventional methods of breeding

Polyploidy breeding in mulberry: Introduction, origin of polyploids, general features of polyploidy, induction of polyploidy and optimal level, special features of triploids, process of triploid mulberry development, varieties developed by polyploidy breeding in mulberry.

Mutation breeding in mulberry: Induction of mutation, bud mutation and chimeras, mutation breeding achievements in mulberry, usefulness of induced mutation, cutting back treatment, limitations and achievements of mutation breeding in mulberry.Breeding for leaf quality, resistance against diseases and pests, tolerance for drought, alkalinity and salinity. Evaluation of mulberry genotypes for different growth and yield parameters. Centres involved in mulberry improvement. Statistical approaches for yield test: Field plot techniques in mulberry breeding experiments. Different experimental designs- RCBD, ARCBD and LSD. Recent approaches in mulberry improvement: *In-vitro* techniques- achievements and prospects.

VII. Practicals

- Floral structure of mulberry;
- Floral biology of mulberry;
- Practising of staggered pruning in mulberry for inducing flowering;
- Sporogenesis: Micro and Megasporogenesis in mulberry;
- Preparation of mitosis slides in mulberry;
- Preparation of meiosis slides in mulberry;
- Study of pollen morphology, pollen fertility and viability;
- Study of stigma receptivity;
- Pollination and crossing techniques in mulberry;
- Characterization of available mulberry germplasm;
- Collection of mulberry fruits, extraction of seeds and raising of seedlings;
- Practising of selection in segregating population/ progenies;
- Study of varietal characteristics of released mulberry varieties;
- Layout of field experiments in mulberry for yield evaluation;
- Techniques of induction of mutants and polyploidy in mulberry;
- Testing for resistance to biotic and abiotic stresses in mulberry;
- Breeding for quality improvement in mulberry;
- Visit to Germplasm research station, CSGRC, Hosur.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text book/ Publication reviews
- Student presentations
- Group work
- Students interview of key policy makers
- Case analysis and case studies, guest lectures
- Review of policy documents

IX. Learning outcome

After successful completion of this course the students are expected to be able to get equipped with the different breeding methods for improvement of mulberry.

X. Suggested Reading

Amitabh Sarkar. *Mulberry breeding*. Kalyani publication, New Delhi.

Chakraborti SP, Roy Chowdhuri S and Bindroo BB. 2013. *A text book on mulberry breeding and genetics*. Kalyani publications, New Delhi.

Dandin SB. 1986. *Mulberry breeding for tropics*. In "*Lectures on Sericulture*" Edt. (G. Boraiah), Suriamya Publishers, Bangalore, pp. 25-28.

Das BC and Krishnaswami S. 1969. *Estimation of components of variation of leaf yield and its traits in mulberry*. *Indian J. Seric.,* **9**(1): 26-30.

Das BC. 1983. *Mulberry taxonomy, cytology and breeding. National Seminar on Sericulture Research and Development,* CSB, pp.1-9.

Das BC and Katagiri K. 1968. *Germination and storage of pollen on its viability*. *Indian J. Seri.,* **10**(1): 37-41.

FAO. Manual of sericulture Vol-1.

Giridhar K. 1996. *Studies on some improved varieties of mulberry and their influence on the silkworm*, *Bombyx mori* L. Ph. D. Thesis, Mysore University, Mysore, India.

Jalaja KS and Ram Rao DM. 2008. *Characterization of seven mulberry genotypes for their leaf quality and bioassay with silkworm*, *Bombyx mori* L. *Sericologia*, **48**(1):85-93.

Machii H, Koyama A, Yamanuchi H and Katagiri K. 1997. *Manual for the characterization and evaluation of genetic resources. Misc. Natl. Inst. Seri. Entomol. Sci.,* **22**: 105-124.

Machii M. 1990. *Leaf disc transformation of mulberry plant* (*Morus alba* L.) by *Agrobacterium* Ti plasmid. *J. Seric. Sci. Japan*, **59**: 105-110.

Masilamani S, Reddy AR, Sarkar A, Sreenivas BT and Kamble CK. 2000. *Heritability and genetic advance of quantitative traits in mulberry* (*Morus* spp.). *Indian J. Seric*., **13**(1): 16-20.

Mogili T, Sarkar A Reddy and Munirathnam 2002. *Effect of saliniy stress on some improved varieties of mulberry*, *Morus spp*. *Sericologia*, **42**(2): 149-163.

Oka S and Tewary PK. 2000. *Induction of hairy roots from hypocotyls of mulberry* (*Morus indica* L.) by Japanese wild strains of *Agrobacterium rhizogeiles*. *J. Seric. Sci. Japan*, **69**: 13-19.

Rangaswami G, Narasimhanna MN, Kasiviswanathan K, Sastry CR and Jolly MS. 1978. *Manual of Sericulture. Vol. 1 Mulberry Cultivation*, FAO, Rome, p.150.

Sarkar A and Fujita H. 1993b. *Japanese system of mulberry breeding: First selection*. *Indian Silk*, September, 9-14.

Sarkar A, Jalaja Kumar S and Datta RK. 2000. *Gradual improvement of mulberry varieties under irrigated condition in South India and the optimal programme for varietal selection in the tropics*. *Sericologia*, **12**: 142-148.

Sastry CR. 1984. *Mulberry varieties, exploitation and pathology*. *Sericologia,***24**(3): 333-359.

Singh BD. *Plant breeding Principles and methods*. Kalyani publication, New Delhi.

Susheelamma BN, Jolly MS, Sharma Giridhar K, Dwivedi NK and Suryanarayana N. 1988. *Correlation and path analysis in mulberry under stress and non-stress conditions*. *Sericologia,* **28**(2): 239-243.

Journals

- *Bulletin of Indian Academy of Sericulture*, CSTRI, Berhampore
- *Indian silk,* CSB, Bangalore
- *Journal of Sericultural Science of Japan,* Japan
- *Seridoc*, CSRTI (CSB), Mysore
- *Sericologia*, ISC, Bangalore
- *Korean Journal of Sericulture*, Korea
- *Indian Journal of Sericulture*, CSRTI (CSB), Mysore
- And other Periodicals, Journals, Reports, Brochures, etc.

Websites

- www.csb.gov.in/
- https://www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Systematics and Morphology of Sericigenous insects

II. Course Code : SER 506

III. Credit Hours : 1+1

IV. Why this course ?

This course gives an impetus to study the morphological differences among sericigenous insects and to define new eco-races adopting morpho taxonomy, chemo taxonomy; to establish and explore new sericigenous fauna in different agro climatic zones.

V. Aim of the course

To inculcate basic systematics study among the students and to explore new fauna among sericigenous group of insects. Defining new genara, species and tribes in sericigenous insects in various habitats of different Agro-climatic zones of Karnataka/ India

The course is organized as follows:

No	Blocks	Units
1.	Morphological studies	I Introduction to Morphology II Morphology of integument III Morphology of body segments and appendages
2.	Systematics of sericigenous insects	I Introduction, scope and methods II Type concept III Preparation of keys IV Zoological nomenclature

VI. Theory

BLOCK 1: Morphological studies

Unit 1: Introduction to morphology

Introduction, general morphology with special reference to the morphology of sericigenous insects.

Unit 2: Morphology of integument

Structure, segmentation and out growths, body regions, appendages and other structures, their modifications in general.

Unit 3: Morphology of body segments and appendages

Morphology of head, thorax, abdomen and their appendages, antennae, mouthparts, setae, legs, cerci, styli and others. Morphology of reproductive organs – modifications.

BLOCK 2: Systematics of sericigenous insects

Unit 1: Introduction, scope and methods

Introduction to systematics: Concept, scope and applications, methods involved in systematics.

Unit 2: Type concept

Holotype, syntype, erection of type and preservation of type.

Unit 3: Preparation of keys

Key formation for sericigenous insects to identify orders, families, genera, species and tribes/ eco-races.

Unit 4: Zoological nomenclature

Binomial nomenclature; concept, scope and application.

VII. Practicals

- Study of head of sericigenous insects;
- Study of thorax and abdomen of sericigenous insects;
- Study of integument, their processes, out growths and setal maps;
- Preparation of temporary/ permanent slides to study the processes;
- Drawing of sketches using grid and camera lucida;
- Collection and preservation of specimens – whole specimen, dry/ wet preservation, labelling of the specimens;
- Study of type concept – Hollotype, Syntype and allotype;
- Preparation of keys to orders, families, genera, species and tribes;
- Study of different sericigenous insects by making diagrams;
- Study of Chaetotaxy in sericigenous insects;
- Study of immature stages of silkworm *Bombyx mori* L.;
- Study of immature stages of Tropical Tasar silkworm;
- Study of immature stages of Eri silkworm;
- Study of Polymorphism in silkworm *Bombyx mori* L., Tropical Tasar and Eri silkworm;
- Field visits for collection of Non-mulberry silkworms;
- Collection and preservation of sericigenous insects (Dry preservation);
- Collection and preservation of immature stages of sericigenous insects (Wet preservation);
- Visit to Taxonomic section of department of entomology to understand preservation of specimens and their management.

VIII. Teaching Methods/ Activities

– Lectures
– Collections, preservation of specimens and submission of different species of sericigenous insects
– Drawing of specimens – habitat sketches using camera lucida and grids
– Photography of specimens using scientifically advanced camera
– Micro photography/ photo microscopy of specimens
– Preparation of permanent slides
– Assignments (Reading/ Writing)
– Text Books
– Student presentations
– Experimentation
– Group discussion
– Group work
– Laboratory exercises
– Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected

- To identify the sericigenous fauna
- To understand the basic principles of morphology
- To understand the basic principles of systematics
- Understanding the Type concept, erection of types
- To establish confidence in systematics of sericigenous insects

X. Resources

Dilip De Sarkar. 1998. *The Silkworm – Biology, Genetics and Breeding*. Vikas Publishing House Pvt. Ltd., New Delhi.

Imms AD. 1961. *General Text Book of Entomology*. 9th Edn., Rev. by O.W. Richards & R.G. Davies, Bombay.

Saxena AB. 1996. *Development of Behaviour in Insects*. Anmol Publications Pvt. Ltd., New Delhi.

Saxena AB. 1996. *Principles of Insect Morphology*. Anmol Publications Pvt. Ltd., New Delhi.

Saxena AB. 1996. *Ecology of Insects*. Anmol Publications Pvt. Ltd., New Delhi.

Journals

- *Bulletins of Sericultural Experimental Station* - Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - Published by NASSI, Bangalore.
- *Indian Silk* - Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* - Department of Sericulture, Government of Karnataka, Bangalore.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Silkworm Egg Production Technology

II. Course Code : SER 509

III. Credit Hours : 1+1

IV. Why this course ?

The silk cocoon yield and productivity directly depend on quality of silkworm eggs produced and distributed to the farmers. The silkworm egg production should be organized and handled scientifically for good quality disease free egg production at both seed and at commercial egg production. The present course is designed to make the student understand the organization of egg production and Acts associated with silkworm seed production, establishment of grainage, grainage equipments, activities, mother moth examination for disease free layings, egg incubation and preservation schedules, production of hybrid seeds and economics of egg production.

V. Aim of the course

The course is formulated with the aim of equipping the PG students with best scientific and practical knowledge on all the activities of egg production starting from organizational setup of seed production, grainage equipment, grainage activities, mother moth examination for producing student community of scientific and high technology expertise.

The course is organised as follows:

No.	Blocks	Units
1.	Organization of egg production	I Three tier multiplication of silkworm seeds II Seed Act
2.	Grainage	I Establishment of grainage II Grainage activities
3.	Artificial Hatching of eggs	I Production of hybrid eggs II Artificial methods of hatching

VI. Theory

BLOCK 1: Organization of egg production

Unit 1: Three tier multiplication of silkworm seeds

Organization of egg production. Breeder stock, foundation stock and commercial egg production (egg cards and loose egg preparation).

Unit 2: Seed Act

Seed legislative act, 1959. Seed Act 2010.

BLOCK 2: Grainage

Unit 1: Establishment of grainage

Location of grainage, plan of grainage, grainage equipments and capacity of grainage.

Unit 2: Grainage activities

Seed areas, seed cocoon market, procurement and transportation of seed cocoons, selection, storage, handling and processing of seed cocoons. Sex separation in pupal stage, moth emergence, synchronization of moth emergence, pairing, depairing, moth examination, laying preparation on egg cards/ loose egg production, rejection of defective eggs, disinfection and washing and incubation of eggs.

BLOCK 3: Artificial Hatching of eggs

Unit 1: Production of hybrid eggs

Production of hybrid seeds (Multivoltine × Bivoltine), (Bivoltine × Bivoltine), (Bivoltine × Bivoltine) × (Bivoltine × Bivoltine) (Double Cross Hybrid). Grainage pests. Economics of egg production and special determinants.

Unit 2: Artificial methods of hatching

Artificial methods of hatching of bivoltine eggs, cold and hot acid treatments, physical and chemical methods, hibernation schedules.

VII. Practicals

- Silkworm breeds and their classification;

- Study of ground plan of model grainage building;
- Study of grainage equipments;
- Preliminary examination of seed cocoons for production of dfls, study of handling and processing of seed cocoons;
- Study of sex separation at pupal and adult stages;
- Study of Silkworm egg incubation;
- Study of silkworm egg hibernation schedules;
- Study of grainage pests and their management;
- Preservation of male moths for reuse;
- Preservation of male and female pupae for synchronization;
- Effect of mating duration on egg production and fertility status of eggs;
- Disinfection of grainage equipments;
- Designation of multivoltine and bivoltine seed areas in Karnataka;
- Estimation of cocoon requirement for production of unit number of DFLs;
- Production of non-hibernating eggs of silkworm;
- Production of hibernating eggs of silkworm (on egg cards and loose egg preparation);
- Artificial hatching of silkworm eggs through acid treatment;
- Economics of silkworm egg production.

VIII. Teaching Methods/ Activities

– Lectures
– Assignments (Reading/ Writing)
– Text Books
– Student presentations
– Experimentation
– Group discussion
– Group work
– Laboratory exercises
– Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the organization of silkworm seed production structure, Grainage, silkworm egg production, seed act, artificial methods of hatching, egg incubation and hibernation schedules
– Utilize this knowledge in producing healthy and quality seed production, serve the farming community with scientific grainage techniques for quality egg production.

X. Suggested Reading

Anonymous. 1997. *Silkworm Egg Production*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Dandin SB and Gupta VP. 2002. *Advances in Indian Sericulture Research*. CSR&TI, Mysore.

Datta RK. 1996. *Global Silk Scenario – 2001. Proceedings of the International Conference on Sericulture – 1994,* Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Narasimhanna MN. 1998. *Manual on Silkworm Egg Production*. CSB, Bangalore.

Journals

- *Bulletin of Sericultural Experimental Station* - Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.

- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Published by Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* - Department of Sericulture, Government of Karnataka, Bangalore.
- *Current Science* – Indian Institute of Science, Bangalore.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Silkworm Rearing Technology

II. Course Code : SER 510

III. Credit Hours : 1+1

IV. Why this course ?

Silkworm rearing is the main contributing factor and plays a major role in quality cocoon production. It is important to know the different silkworm rearing methods for rearing young and late-age silkworms. The knowledge on scientific methods starting from egg incubation, black boxing, brushing, young age rearing, late age rearing, mounting of ripe silkworms, maintenance of environmental conditions during silkworm rearing, care during mounting, etc., is very important for sericulture experts to lead the sericulture community with a scientific and technical expertise.

V. Aim of the course

The course is designed with the aim of equipping the PG students with the best scientific knowledge and technical expertise in the field of silkworm rearing technology, different methods/ techniques involved in silkworm rearing, maintenance of environmental condition during rearing, etc., for quality silkworm production inturn contributing to the economy of individual farmer.

The course is organised as follows:

No.	Block	Units
1.	Planning for silkworm rearing	I Planning for chawki rearing and late age silkworm rearing II Disinfection and disinfectants III Mulberry leaf preservation IV Incubation of silkworm eggs
2.	Silkworm rearing	I Early instar silkworm rearing II Late age silkworm rearing
3.	Mounting, harvesting and marketing of silk cocoons	I Mounting of ripe worms and cocoon marketing III Comparison of different rearing methods

VI. Theory

BLOCK 1: Planning for silkworm rearing

Unit 1: Planning for chawki rearing and late age silkworm rearing

Planning for rearing, criteria to be considered for rearing, plan of rearing house for chawki and late age silkworm rearing, rearing equipment, measurement and regulation of environmental factors.

Unit 2: Disinfection and disinfectants

Disinfection of rearing room and equipment.

Unit 3: Mulberry leaf preservation

Planning for silkworm rearing; harvesting, transportation and preservation of mulberry leaves.

Unit 4: Incubation of silkworm eggs

Different methods of incubation of silk moth eggs, black-boxing, hatching and brushing.

BLOCK 2: Silkworm rearing

Unit 1: Early instar silkworm rearing

Early instar silkworm (Chawki) rearing, different methods, environmental conditions, quality of leaf, feeding, bed cleaning, spacing. Chawki rearing centres.

Unit 2: Late age silkworm rearing

Different methods of late age silkworm rearing, environmental conditions, feeding and bed spacing. Management of silkworm during moulting.

BLOCK 3: Mounting,harvesting and marketing of silk cocoon

Unit 1: Mounting of ripe worms and cocoon marketing

Mounting of ripe worms, different kinds of mountages. Rearing house and equipment for shoot method of rearing.

Unit 2: Comparison of different rearing methods

Comparing shoot feeding and shelf method of rearing.

VII. Practicals

- Ground plan for model rearing house for shelf method of rearing;
- Chemical and physical agents used in silkworm rearing and disinfection;
- Rearing equipments for shelf method of rearing;
- Incubation of silk moth eggs and black- boxing;
- Hatching and brushing;
- Early instar silkworm rearing;
- Late age silkworm rearing;
- Regulation of environmental conditions for silkworm rearing;
- Harvesting and preservation of mulberry leaf;
- Management of silkworms during moulting;
- Mounting of ripe silkworms;
- Cocoon harvesting, grading, transportation and marketing;
- Rearing house and equipment for shoot method of rearing;
- Shoot feeding for late age silkworm rearing;
- Harvesting and preservation of mulberry shoots;
- Spacing and bed cleaning in shoot feeding method of silkworm rearing;
- Economics of silkworm rearing;

- Rearing from brushing to mounting for seed and silk production.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand thoroughly the scientific silkworm rearing techniques, scientific management of silkworms during special conditions like during mounting, mulberry care, spinning stage, etc., inturn contributing to build a technically competent Sericultural expertise.

X. Suggested Reading

Anonymous. 1998. *Illustrated Textbook on Sericulture*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Boraiah G. 1994. *Lectures on Sericulture*. SBS Publishers, Bangalore.

Dandin SB and Gupta VP. 2002. *Advances in Indian Sericulture Research*. CSR&TI, Mysore.

Dandin SB, Jayant Jayaswal and Giridhar K. (Eds.) 2003. *Handbook of Sericulture Technologies*. CSB, Bangalore.

Datta RK. 1996. *Global Silk Scenario – 2001. Proceedings of the International Conference on Sericulture – 1994.* Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Govindan R, Chinnaswamy KP, Krishnaprasad NK and Reddy DNR. 2000. *Advances in Tropical Sericulture. Vol. 4– Proceedings of NSTS – 1999,* UAS, Bangalore.

Govindan R, Devaiah MV and Rangaswamy HR. 1978. *Reshme Vyavasaya (Kannada)*. UAS, Bangalore.

Hiroo and Sibuya-ku. 1975. *Textbook of Tropical Sericulture*. Japan Overseas Corporation Volunteers, Tokyo, Japan.

Krishnaswami S, Narasimhanna MN, Suryanarayan SK and Kumararaj S. 1973. *Sericulture Manual-2 - Silkworm Rearing*. Agriculture Service Bulletin, FAO, Rome.

Rajan RK and Himantharaj HT. 2005. *Silkworm Rearing Technology*. Central Silk Board, Bangalore.

Ramakrishna Naika, Govindan R and Sannappa B. 2002. *Organic Sericulture*. Seri Scientific Publishers, Bangalore.

Tanaka Y. 1964. *Sericology*. Central Silk Board, Bangalore.

Tazima Y. 1972. *Handbook of Silkworm Rearing*. Fuji Pub.Co. Ltd., Tokyo, Japan.

Ullal SR and Narasimhanna MN. 1981, *Handbook of Practical Sericulture*. CSB, Bangalore.

Yasuji Hamamura. 2001. *Silkworm Rearing on Artificial Diet*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Yonemura M and Rama Rao N. 1925. *Handook of Sericulture*. Mysore Government Branch Press.

Journals

- *Bulletin of Sericultural Experimental Station* - Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.

- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Genetics and Breeding of Silkworms

II. Course Code : SER 511

III. Credit Hours : 1+1

IV. Why this course ?

Silkworm crop improvement needs sustainable efforts in order to achieve higher silk productivity of superior quality. Understanding of genetic basis of expression of characters and application of this understanding for breeding silkworms that meet the present day scenario is essential. Hence, this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of silkworm genetics and principles of silkworm breeding. The subject is addressed to understand reproductive biology, hereditary traits and principles of silkworm breeding
The course is organized as follows:

No	Blocks	Units
1	Genetics of silkworm	I Cytology II Reproductive biology III Inheritance of characters
2	Breeding of silkworm	I Silkworm breeding resources II Methods of silkworm breeding

VI. Theory

BLOCK 1: Genetics of silkworm

Unit 1: Cytology

Ancestor and cytological basis of origin of silkworms. Cytological aspects of silkgland and achievements in deciphering molecular biology of silk gene. Hormonal control mechanisms.

Unit 2: Reproductive biology

Phenomena of spermatogenesis and oogenesis with relevance to crossing over, cell division types in silkworms, synaptonemal complex, fertilization, chromosomes in silkworms. Sex determination, parthenogenesis, polyploidy, mosaics.

Unit 3: Inheritance of characters

Hereditary traits of importance in egg, larva, pupa-cocoon and adult.

E- Group as a tool in genetics and significance. Linkage groups in silkworms. Sex linked inheritance, Quantitative and Qualitative Characters in silkworm breeding. Genetics of cocoon colours. *Bombyx mori* L. genome and latest genome sequence, Translocation of characters in metamorphic stages.

BLOCK 2: Breeding of silkworm

Unit 1: Silkworm breeding resources

Multivoltine and bivoltine races and hybrids. Silkworm germplasm and resource potential.

Unit 2: Methods of silkworm breeding

Methods of silkworm breeding and their importance with relevance to Indian scenario. Breeding for thermotolerance, disease resistance, special characters required for the nation and also for silk export. Sex linked and sexlimited races- their importance and need of the hour, Authorization and release of silkworm races.

VII. Practicals

- Study of mitosis and meiosis in silkworm;
- Study of oogenesis in silkworm;
- Study of spermatogenesis and fertilization in silkworms;
- Study of important hereditary traits in egg and larva of silkworm *Bombyx mori* L.;
- Study of important hereditary traits of pupa and cocoons of silkworm *Bombyx mori* L.;
- Study of important hereditary traits of adult *Bombyx mori* L.;
- Study of Marker genes and linkage groups in silkworm;
- Study of heterosis - working out heterosis, heterobeltiosis and standard heterosis for economic characters;
- Study of silkworm germplasam;
- Study of biometrical methods in silkworm breeding;
- Study of modern methods of silkworm breeding;
- Study of induction of parthenogenesis in silkworm breeds;
- Study of induction of polyploidy in silkworm breeds;
- Study of conventional methods of silkworm breeding;
- Study of breeding of newly evolved silkworm breeds;
- Study of breeding of non-mulberry silkworms;
- Study of breeding plans;
- Visit to CSGRC,CSB, Hosur.

VIII. Teaching Methods/ Activities

– Lectures
– Assignments (Reading/ Writing)
– Text Books
– Student presentations
– Experimentation
– Group discussion
– Group work
– Laboratory exercises
– Visits to Germplasam centers
– Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the reproductive biology, inheritance of traits and breeding methods
- Utilise this knowledge to plan for silkworm breeding activities.

X. Suggested Reading

Anonymous. 1993. *Principles and Techniques of Silkworm Breeding*. ESCAP, UN, New York. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. p.111.

Gardner EJ, Simmons MJ and Snustad DP. 1991. *Principles of Genetics,* John Willey& Sons Inc., New York. p. 649.

Hiratsuka E. 1999. *Silkworm Breeding*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. p. 500.

Jolly MS, Sen SK, Sonwalker TN and Prasad GK. 1979. *Non-mulberry Silks*. FAO - Agricultural Service Bulletin, Rome. p. 178.

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Sarin C. 1990. *Genetics*. Tata McGraw – Hill Publishing Co. Ltd., New Delhi. p. 528.

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- *Bulletins of Sericultural Experimental Stat*ion - Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Published by Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada*) - Department of Sericulture, Government of Karnataka, Bangalore.
- *Current Science* – Indian Institute of Science, Bangalore.

Websites

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- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Diseases and Pests of Silkworm

II. Course Code : SER 512

III. Credit Hours : 1+1

IV. Why this course ?

Silkworms are affected by a number of diseases caused by Microsporidia, fungi, viruses, bacteria and mixed infections and also attacked by insect pests. The exposure to these pathogens and pests results in mortality of silkworms and economic loss to the silkworm rearers. A better understanding of causative agents, symptoms, sources of infection, predisposing factors, transmission and management of silkworm diseases and pests is very important to improve cocoon productivity and maximize economic benefit to silkworm rearers by better avoidance/ management of silkworm diseases and pests.

V. Aim of the course

The course is designed to provide both theory and practical knowledge regarding the subjects of Classification of disease-causing organisms of mulberry and non-mulberry silkworms including viral, fungal, bacterial, protozoan and mixed infections. Knowledge on their occurrence, causative agent, etiology, symptoms and infection, sources of infection, predisposing factors, transmission and management, symptoms, seasonal incidence of diseases associated with mulberry and non-mulberry silkworms is important. Diagnosis of different pathogens based on symptoms (external and internal), regulation of environmental factors contributing to diseases, prevention and control of diseases also attain importance. Know how on pests of mulberry and non-mulberry silkworms, uzi fly occurrence, nature and extent of damage, life-cycle and management, other pests and predators effecting silkworm crop and their management and pesticide toxicity/ residual toxicity, use of eco-friendly pesticides and biological control will also be dealt.

The course is organized as follows:

No	Blocks	Units
1.	Silkworm diseases and their management	I Importance and Classification II Silkworm pathogens, disease development and diagnosis III Management of silkworm diseases
2	Silkworm pests and their	I Ujifly, *Exorista bombycis* Louis—a major pest of silkworms. II Other pests and predators affecting silkworm crop and their management. III Pesticide toxicity

VI. Theory

BLOCK 1: Silkworm diseases and their management

Unit 1: Importance and classification

Taxonomic position of silkworm disease causing organisms including viruses, bacteria, fungi, protozoans, classification of various pests causing economic loss to silkworms, and their importance.

Unit 2: Silkworm pathogens, disease development and diagnosis

Occurrence, causative agent, symptoms and infection, source of infection, predisposing factors, seasonal incidence, transmission and management of the pathogens individually including viral, fungal, bacterial, protozoan and mixed infections. Diagnosis of different pathogens based on symptoms (external and internal), patho-physiology and histopathology.

Unit 3: Management of silkworm diseases

Comparative etiology of silkworm pathogens. Management, prevention and control of diseases of silkworms, regulation of predisposing and environmental factors contributing to diseases, rearing disease resistant breeds of silkworm. Management of alternative hosts of silkworm disease causing pathogens (lepidopteran crop pests and pests of mulberry). Intergrated disease management.

BLOCK 2: Silkworm pests and their management

Unit 1: Ujifly, *Exorista bombycis* Louis - a major pest of silkworms

History and taxonomy, Bio-ecology, Life cycle-egg, maggot, pupa, adult, oviposition, damage and extent of damage caused, prevention and control, biological control and IPM.

Unit 2: Other pests and predators affecting silkworm crop and their management

Pests and predators causing loss to silkworms and cocoons including Ants, type of damage, management. Straw itch mite, life cycle, kind of damage, management.

Dermestid beetles, classification, life cycle, nature of damage, management. Rats, squirrels, lizards, earwigs, etc.,

Unit 3: Pesticide toxicity

Poisoning by agricultural chemicals to silkworms, acute and chronic symptoms of poisoning by different agricultural chemicals. Residual toxicity of chemicals on mulberry and damage caused, prevention and control.

VII. Practicals

- Sterilization techniques for isolation of silkworm pathogens;
- Isolation and purification of *Bm*NPV;
- Isolation and purification of *Bm*CPV;
- Isolation and purification of *Bm*IFV and *Bm*DNV;
- Isolation and purification of white muscardine fungus *Beauveria bassiana* from silkworm *Bombyx mori;*
- Isolation and purification of brown muscardine fungus *Aspergillus tamarii* from silkworm *Bombyx mori;*
- Isolation and purification of bacteria from the gut and haemolymph of silkworm *Bombyx mori;*
- Study of life cycle, symptoms and diagnosis of *Bm*NPV;
- Study of life cycle, symptoms and diagnosis of *Bm*CPV;
- Study of life cycle, symptoms and diagnosis of *Bm*IFV and *Bm*DNV;
- Study of life cycle, symptoms and diagnosis of silkworm microsporidiosis;
- Study of life cycle, symptoms and diagnosis of white and green muscardines;
- Study of bacteria invading the digestive system and haemolymph;
- Study of bacterial toxicosis in mulberry silkworm;
- Intergrated management for prevention of silkworm diseases;
- Study of life-cycle of silkworm ujifly and its management;
- Study of life cycle and management of dermestid beetles;
- Visit to sericulture farmers fields.

VIII. Teaching Methods/ Activities

– Lectures

- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the scientific foundation of silkworm protection and relate the key learning for further scientific research in the area of silkworm protection.
- Utilise methods and tools for prevention and management of diseases and pests of silkworms.
- Utilise material in scientific publications relevant for silkworm protection for enhancing cocoon crop productivity through effective management of silkworm diseases and pests.

X. Suggested Reading

Dandin SB and Giridhar K. 2014. *Handbook of Sericulture Technologies*; Central Silk Board, Ed., Dr., pp 247.

Govindan R, Narayanaswamy TK and Devaiah MC. 1998. *Principles of Silkworm Pathology,* p.420.

Nataraju B, Sathyaprasad K, Manjunath D and Aswani Kumar C. 2005. *Silkworm Crop Protection*. Central Silk Board, Bangalore, pp. 1-285.

Pringle Jameson A. 1984. *Report On The Diseases of Silkworms In India*, IBS, New Delhi, pp. 1-64.

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- *Bulletins of Sericultural Experimental Station* - Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Published by Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* - Department of Sericulture, Government of Karnataka, Bangalore.

Websites

- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Silk Technology-I

II. Credit Hours : 1+1

III. Course code : SER 514

IV. Why this course ?

Sericulture is an agro based industry, which concentrates on production of quality leaf, cocoon and raw silk. The raw silk production by reelers from different machineries plays an important role in fabric production. Therefore, cocoon is considered as raw material for silk reeling industry which has to be processed by adopting recent techniques in all aspects of reeling that aim at quality raw silk production. The knowledge on recent techniques serves as an effective tool in reeling cocoons which throws light to produce competitive technical man power in processing of raw material. Hence is this course.

V. Aim of the course

The course is designed to make the students to get acquainted with activities in different reeling units operated both in private and government sectors. These activities will help in learning all techniques of silk reeling for quality raw silk production. In addition, they get knowledge on responsibilities of reeling units on management of labour and exploitation of reeling waste generated for by-product utilization.

Organisation of course:

No.	Blocks	Units
1	Cocoon as raw material	I Physical characteristics
		II Commercial characteristics
2	Transaction of cocoons	I Defective cocoons
		II Cocoon marketing
3	Steps in silk reeling	I Cocoon stifling
		II Cocoon cooking and brushing
		III Cocoon reeling
		IV Re-reeling
		V Reeling water
4	Silk testing and examination	I Different methods of silk examination
		II Silk testing and grading
5	Post reeling technology	I Doubling, twisting and weaving
		II Marketing of raw silk.

VI. Theory

BLOCK 1: Cocoon as raw material

Unit 1: Physical characteristics

Introduction; Importance and use of silk, cocoon quality. Physical characteristics- cocoon colour, shape, size, wrinkles, uniformity and compactness.

Unit 2: Commercial characteristics

Cocoon weight, shell weight, shell percentage, filament length, denier, non-breakable filament length, reelability and raw silk percentage.

BLOCK 2: Transaction of cocoons

Unit 1: Defective cocoons

Types of defective cocoons, reasons for defective cocoons, cocoon sorting, methods of sorting, estimation of defective cocoons per kg. Technological aspects. Selection of raw material for silk reeling – scientific method of testing and classification of cocoons.

Unit 2: Cocoon marketing

Marketing based on visual observation and based on quantitative parameters, open auction system (Quality based pricing) and E-transaction. Limitations of open auction system and estimation of renditta.

BLOCK 3: Steps in silk reeling

Unit 1: Cocoon stifling

Definition, different methods of stifling of cocoons - sun drying, steam stifling, hot air drying (shelf carrier type, Tunnel type, Band type- hot air circulating, air heating type and one step band type) and other methods. Effect of storage on stifling. Moisture percentage, Phenomenon of cocoon drying, drying percentage, equilibrium moisture percentage (Phenomenon of moisture evaporation). Effect of cocoon thickness and compactness on cocoon stifling, advanced system of cocoon stifling and machineries.

Unit 2: Cocoon cooking and brushing

Cocoon cooking- objectives of cocoon cooking, effect of pressure and temperature on infiltration of water into cocoon cavity, swelling of sericin layer, different methods of cooking (Open pan, two pan and three pan cooking system). Brushing of cocoons, different methods of brushing. Effect of temperature on solubility of sericin and fibroin layers, dipping period and brushing.

Unit 3: Cocoon reeling

Cocoon reeling- definition, different methods of reeling (Open/ Floating/ Sunken), Importance of croissure, length of the croissure and croissure angle and silk reeling, reeling machineries – Silk reeling on charaka, cottage basin, multiend, semi automatic and automatic reeling machines.

Unit 4: Re-reeling

Re-reeling, reel permeation, different methods of permeation, re-reeling methods, advantages and disadvantages of open re-reeling and closed type of re-reeling.

Unit 5: Reeling water

Reeling water: Different sources of water used in reeling, characteristics/ Properties of water (Impurities of water), Physical and chemical properties of water, Importance of reeling water, water qualities suggested by Kim and amelioration of water, different methods of amelioration (aeration, filtration, sedimentation and ion exchange method), amelioration of reeled water and reuse of water after treatment.

BLOCK 4: Silk testing and examination

Unit 1: Different methods of silk examination

Different silk examination methods and lacing, book and bale making.

Unit 2: Silk testing and grading

Silk testing and grading-grading of raw silk based on I.S.A., silk testing tools for physical (visual inspection) and mechanical properties of silk. Procedure adopted for conducting physical and mechanical properties of silk and equipments used for testing of raw silk.

BLOCK 5: Post reeling technology

Unit 1: Doubling, twisting and weaving

Silk throwing, weaving, warping and wefting, silk doubling and twisting, by-products of reeling units, types of reeling waste (brushing waste, reeling waste, cooking waste, re-reeling waste, throwing waste and pelade layer) as raw material for spun silk industry.

Unit 2: Marketing of raw silk

Factors influencing the assessment of rawsilk quality. Role of silk exchange, auctioning of raw silk based on physical and mechanical properties and economics of silk reeling.

VII. Practicals

- Classification of cocoons of silkworm breeds;
- Study of Physical and Commercial characters of cocoons;
- Study of mode and time of cocoon transportation and marketing;
- Cocoon sorting, methods and estimation of defective cocoons;
- Cocoon stifling methods and estimation of drying and moisture percentage;
- Practising of cocoon cooking and brushing methods;
- Estimation of reeling and cooking waste percentage;
- Reeling appliances and practising reeling on Charaka and improved Charaka;
- Study of reeling appliances and practising reeling on Cottage basin and Domestic basin;
- Visit to government filature to acquaint with large scale reeling on Multiend reeling machine;
- Visit to Automatic reeling machine unit at Ramanagara;
- Silk examination, skein making and book making;
- Study of Reeling water and its quality;
- Amelioration of silk reeling water and its importance;
- Study of physical properties of mulberry raw silk;
- Study of microscopic examination of silk bave;
- Study of quality tests of raw silk and By-products in silk reeling;
- Visit to Central silk technological research institute, Bengaluru.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After undergoing this course the students are able to assess the quality of cocoon as raw material for reeling industry and acquaint with different techniques of reeling in quality silk production.

X. Suggested Reading

Bhaskar RN and Govindan R. 2005. *Techniques in Silk Reeling*, Department of Sericulture, UAS,GKVK, p.50.

Ganga G. 2003. *Comprehensive Sericulture.* Volume 2. *Silkworm Rearing and Silk Reeling.* Oxford & IBH, New Delhi, p.429.

Kamal Jaiswal, Sunil P Trivedi, Pandey BN and Tripathi AK. *Mulberry sericulture problems and prospects*, A P H publishing corporation, New Delhi.

Kim BH. 1978. *Raw Silk Reeling*, Korean edition Seoul Publishing Company, P 275.

Krishnaswami S, Madhava Rao NR, Suryanarayan SK and Sundaramurthy TS. 1972. *Manual on Sericulture-III.Silk Reeling,* FAO, Rome, p.112.

Mahadevappa D, Halliyal VG, Shankar AG and Bhandiwad R. *Mulberry silk reeling technology*, Oxford & IBH publishing Co. Pvt. Ltd.

Manual on Bivoltine silk Reeling Technology. 2003. Published by JICA, PPP BST Project, p.122

Savithri, Sujathamma and Neeraja, *Sericulture industry: An overview*.

Tripurari S. *Sericulture and silk industry, Consortium on rural technology*, Madhuvan, Delhi.

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- *Bulletins of Sericultural Experimental Station* - Suginami, Tokyo, Japan.
- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* - Department of Sericulture, Government of Karnataka, Bangalore.

Websites

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- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Non-mulberry Sericulture

II. Course Code : SER 515

III. Credit Hours : 1+1

IV. Why this course ?

This course enlightens various types of silk producing insects, viz., Tasar, Eri and Muga and their production techniques. Thishighlights wild rearing in-situ in forest area and also semi domestication of wild non-mulberry silks. This also helps to explore possibilities of new sericigenous insects and other minor silk producers.

V. Aim of the course

This course is designed to provide basic and applied aspects of non-mulberry sericulture. This course will approach multi-disciplinary perspective, it aims to equip students to identify, evaluate and explore new species of sericigenous insects to address the tribals self employment programme.

The course is organized as follows:

No	Blocks	Units
1.	Underexploited non-mulberry silks	I Scope, importance, distribution in the World II Introduction to Anaphe, Coan and Fagara silks
2.	Commercially exploited non-mulberry silks	I Scope, importance and their distribution in the World II Rearing of Eri silkworms III Rearing of Tasar (tropical/ temperate) IV Rearing of Muga silkworms V Economics of non-mulberry silkworm rearing

VI. Theory

BLOCK 1: Underexploited less known non-mulberry silks

Unit 1: Scope, importance and distribution in the World

Uses of less known sericigenous species for commercial exploitation, distribution pattern on different host plants and their statistics.

Unit 2: Introduction to Anaphe, Coan and Fagara silks

Systematics, morphology and cocoon characteristics of Anaphe, Fagara, Coan silks and possibilities of their exploitation.

BLOCK 2: Commercially exploited non-mulberry silks

Unit 1: Scope, importance and their distribution in the world

Scope, importance, distribution in the country and World of Eri, Tropical Tasar, Temperate Tasar and Muga silks and their primary and secondary host plants.

Unit 2: Rearing of Eri silkworm

Host plant distribution and their classification, agronomic practices and their protection, grainage techniques, rearing of eri using improved techniques and crop protection.

Unit 3: Rearing of Tasar (tropical/ temperate)

Host plant distribution and their classification, agronomic practices and their protection, grainage techniques, rearing of tropical/ temperate tasar using improved techniques and crop protection.

Unit 4: Rearing of Muga silkworms

Host plant distribution and their classification, agronomic practices and their protection, grainage techniques, rearing of muga silkworms using improved techniques and crop protection.

Unit 5: Economics of non-mulberry silkworm rearing

Economics of non-mulberry silkworm rearing, viz., eri, tasar and muga silkworm rearing and their cost benefit ratio.

VII. Practicals

- Study of primary and secondary host plants of eri silkworm;
- Study of primary and secondary host plants of tasar silkworm;
- Study of primary and secondary host plants of muga silkworm;
- Cultivation of popular castor genotypes for eri silkworm rearing;
- Preparation of rearing house for eri silkworm rearing;
- Rearing of eri silkworm on different castor genotypes;
- Calculation of consumption indices in eri silkworm using leaves of different castor genotypes;
- Collection and dry preservation of different primary and secondary host plants of non-mulberry silkworms;
- Preparation of disease free layings of eri silkworm;
- Morphology of eggs and larvae of eri silkworm;
- Morphology of pupa and moth of eri silkworm;
- Morphology of eggs and larvae of tasar and muga silkworms;
- Morphology of pupa and moth of tasar and muga silkworms;
- Effect of different mating durations on fecundity and fertility of eri silk moths;
- Study of different natural enemies of eri silkworm;
- Study of different diseases of eri silkworm;
- Practising of tasar egg production;
- Economics of eri silkworm rearing;
- Visit to Eri Silkworm Seed Production Centre, CSGRC Hosur, CSB.

VIII. Teaching Methods/ Activities

- Lectures
- Collections of various non-mulberry silkworms
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to be able to

- acquire skills on rearing of vanya silks, their host plants and rearing technologies. In addition, it enables to explore less known silkworm species and exploit them.

X. Suggested Reading

Jolly MS, Sen SK and Ahsan MM. 1974. *Tasar culture*. Ambika Publishers, Bombay.

Jolly MS, Sen SK Sonwalkar TN and Prasad GK. 1979, *Sericulture Manual - 4 – Non-Mulberry Silks*. Agriculture Service Bulletin, FAO, Rome.

Sannappa B, Jayaramaiah M., Govindan R and Chinnaswamy KP. 2002, *Advances in Ericulture*. Seri Scientific Publishers, Bangalore.

Sarkar DC. 1980. *Ericulture in India.* Central Silk Board, Bangalore.

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- *Journal of Sericultural Science of Japan* - Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.

- *Sericologia* - Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* - CSR & TI, Mysore.
- *Journal of Sericulture and Technology* - NASSI, Bangalore.
- *Indian Silk* - Published by Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* - Department of Sericulture, Government of Karnataka, Bangalore.

Websites

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Minor Courses
M.Sc. (Agri.) in Sericulture

I. Course Title : Nutrition of Host Plants of Silkworms
II. Course code : SER 503
III. Credit Hours : 1+1
IV. Why this course ?

Silkworm is monophagous insect mainly feeding on mulberry and drawing its nourishment for growth and development. It is mainly dependent on the quality of leaf used for silkworm rearing. Production of quality leaf by adopting standard package of practices to increase biochemical parameters of mulberry which are directly involved not only to improve the quality parameters but also enhance productivity per unit area. Therefore, the technical knowledge on nutritional management of mulberry definitely helps in improving quality parameters of silk. Hence this course.

V. Aim of the course

The main aim of this course is to provide both basic and applied knowledge on nutritional management through different methods and means of application. Further, it also provides nutritional requirement for different growth stages which is required for silkworm growth and development. In addition, the complementary use of chemicals, fertilizers, organic manure and bio-fertilizer is important to maintain and sustain higher level of soil fertility and productivity. The principles of manure and fertilizer application and their toxicity affect on quality parameters of mulberry is the need of the hour. The beneficial effect of optimum nutrition and toxicity due to excess nutrients application and deficiency symptoms due to lack of nutrient availability affect the growth of mulberry. The academic knowledge on the above helps in strengthening the skills of students to serve the farming community effectively who are involved in quality leaf production and success of sericulture.

Organisation of course

No.	Block		Units
1,	Organic manure application	I	Principles of manure application
2	Nutrition of non-mulberry silkworm host plants	I	Nutrition of non-mulberry silkworm host plants
3	Physico-chemical properties of soil and Nutrient uptake	I	Influence of physical and chemical properties of soil
4	Application of major nutrients	I	Principles of fertilizer application.
		II	Role of nitrogen
		III	Role of Phosphorus
		IV	Role of Potash
		V	Role of secondary nutrients
5	Nutrient deficiency	VI	Nutrient deficiencies and toxicity of nutrients

VI. Theory

BLOCK 1: Organic manure application

Unit 1: Principles of manure application

Role of mineral nutrition on growth and development of mulberry, Classification of minerals i.e. organic and inorganic, Types of organic nutrition –FYM, Compost, Pressmud, Animalmanure-Poultry manure, piggery manure, Horse manure, methods of green manuring and composting.

BLOCK 2: Nutrition of non-mulberry silkworm host plants

Unit 1: Nutrition of non-mulberry silkworm host plants

Nutritional aspects of Castor, Tapioca, Terminalia, Soalu and Som.

BLOCK 3: Physico-chemical properties of soil and Nutrient uptake

Unit 1: Influence of physical and chemical properties of soil

Types of mulberry soils, soil structure, texture, CEC, clay and mineral composition, soil pH, micro and macro fauna, organic matter and their influence on growth and development.

Role of physical and chemical properties on nutrient uptake and growth. Absorption pattern of major and micro nutrients in different soils. Response of mulberry varieties on absorption pattern of N, P, K and micronutrients.

BLOCK 4: Application of major nutrients

Unit 1: Principles of fertilizer application

Role of bio-fertilizers –Nitrogen fixing bacteria, phosphate solubilizing fungi, exploitation of K solubilizing organism, VAM, application methods, split application based on soil test for both rainfed and irrigated conditions.

Unit 2: Role of nitrogen

Sources of nitrogen, types and method of application on growth and development and biochemical constituents of mulberry and their effect on rearing parameters.

Unit 3: Role of Phosphorus

Sources of Phosphorus, types and methods of application on growth and development and biochemical constituents of mulberry and effect on rearing parameters.

Unit 4: Role of Potash

Sources of Potash, types and methods of application on growth and development and biochemical constituents of mulberry and effect on rearing parameters.

Unit 5: Role of secondary nutrients

Sources of secondary nutrients, types and methods of application on growth and development and biochemical constituents of mulberry and effect on rearing parameters.

BLOCK 5: Nutrient deficiency

Unit 1: Deficiencies of Major nutrients and their toxicity

Deficiency symptoms of N, P and K toxicity in mulberry plants and their effect on quality of mulberry, correction of the soil by soil application, foliar application and fertigation methods.

Unit 2: Deficiencies of Secondary nutrients and their toxicity

Deficiency symptoms of S, Mn, Fe, Mo, Mg, Ca, Zn and other micronutrients and their toxicity in mulberry plants and their effect on quality of mulberry, correction of the through soil and foliar application and fertigation.

VII. Practical

- Collection of soil samples in mulberry garden and interpretation of soil test results;
- Development of recommended fertilizer schedule for both rainfed and irrigated mulberry;
- Modern methods of vermin-composting techniques by using sericulture wastes;
- Different methods of green manuring and conservation practices;
- Growth and root parameters of mulberry under different moisture regimes;
- Estimation of mulberry yield per unit area in both rainfed and irrigated condition;
- Use of soil amendments on sprouting and rooting pattern in mulberry;
- Pot culture studies on the effect of nutrient solution and bacterial inoculants on the growth of mulberry cuttings;
- Enumeration of beneficial microflora (Bacteria, Fungi and Actinomycetes) in mulberry rhizosphere;
- Induction of deficiency symptoms of major nutrients using sand culture techniques;
- Practising of foliar nutrient application in mulberry;
- Application of conventional methods of fertilizer application in mulberry;
- Practising supply of nutrients to mulberry through fertigation;
- Study of different methods of fertilizer application in mulberry;
- Study on effect of fertilizer use pattern on physico-chemical properties of mulberry soil;
- Supplementation of deficit nutrients for both rainfed and irrigated mulberry schedule as per soil test;
- Enumeration of micro fauna of soils under mulberry cultivation;
- Study of fertilizer use efficiency in mulberry;
- Practising Seri Suvarna Technology (Trenching and Mulching) in mulberry garden.

VIII. Teaching Methods/ Activities

- Lectures
- Providing study material/ lecture material
- Practical manuals
- Assignments (Reading/ Writing)
- Text Books/ Publications/ reviews/ technical bulletins/ manuals/ proceedings of scientific seminars
- Student presentations
- Experimentation
- Group discussions
- Group work

– Laboratory exercises
– Scientific journals and periodicals
– Layout of experiments
– Study visits

IX. Learning outcome

After the successful completion of this course the students are expected to:

- Assess the quantity of manures and fertilizers requirement for rainfed and irrigated mulberry
- Identify the deficiency symptoms of major and micro nutrients
- Adopt IPNM model for productivity enhancement

X. Suggested Reading

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- *Indian Journal of Sericulture* – CSR & TI, Mysore.
- *Journal of Sericulture and Technology* – Published by NASSI, Bangalore.
- *Indian Silk* – Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* – Bhubaneshwar, Orissa.
- *Reshme Krishi (Kannada)* – Department of Sericulture, Government of Karnataka, Bangalore.
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I. Course Title : Mulberry Pests and Diseases

II. Course Code : SER 504

III. Course Credit : 2+1

IV. Why this course ?

Mulberry is key a factor in the production of quality silk cocoon by the silkworm rearers. As nutrient rich silkworm food crop the mulberry also attracting various pests and suffers from diseases. The knowledge on various important pests and diseases affecting mulberry in different seasons, symptoms, their life cycle and different management practices are necessary for quality mulberry leaf production economically. Hence, is this course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge in managing diseases and pests in mulberry eco-system. It helps to equip students to understand different pests infesting mulberry crop at different stages and seasons, diseases affecting mulberry crop and their management so that producing technically competent sericulture manpower for leading sericulture formats towards scientific quality mulberry production.

This course is organized as follows:

No.	Blocks	Units
1	Mulberry diseases and their management	I Fungal diseases II Bacterial diseases III Viral diseases IV Nematode diseases
2	Mulberry pests and their management	I Leaf eating pests (Defoliating pests) II Sucking pests (Sap feeders) III Other Minor pests of mulberry

VI. Theory

BLOCK 1: Mulberry diseases and their management

Unit 1: Fungal diseases

Root rot diseases, powdery mildew, leaf spot and leaf rust diseases. Classification, occurrence, symptoms and damage, extent of crop loss and management.

Unit 2: Bacterial diseases

Leaf blight and Rot diseases-Classification, occurrence, symptoms of damage extent of crop loss and management.

Unit 3: Viral diseases

Leaf mosaic and mulberry dwarf diseases classification, occurrence, symptoms extent of crop loss and management.

Unit 4: Nematode disease

Root knot diseases- Classification, occurrence, symptoms, identification of root knots extent of crop loss and management.

BLOCK 2: Mulberry Pests and their Management

Unit 1: Leaf eating pests (Defoliators)

Mulberry leaf roller, Bihar hairy caterpillar, wingless grasshopper, cutworm, rootgrubs -Classification, status, seasonal incidence, damaged caused symptoms, loss, lifecycle and management.

Unit 2: Sap feeders (Sucking pests)

Thrips, jassids, spiraling whitefly, scale insects, mealy bugs, spider mites -Classification, status, seasonal incidence, damaged caused symptoms, loss, lifecycle and management.

Unit 3: Minor pests of mulberry

Stem borer, termites, May–June beetles, stem girdler beetle - RotsClassification, status, seasonal incidence, damaged caused symptoms, loss, lifecycle and management.

VII. Practicals

- Collection of insect and non-insect pests from mulberry garden and their preservation;
- Classification of mulberry pests based on taxonomy and nature of feeding;
- Classification of mulberry diseases;
- Collection of diseased specimen from mulberry garden and their preservation;
- Classification of mulberry diseases based on taxonomy and parts of the plants damaged;
- Incidence and estimation of damage to mulberry caused by mulberry leaf webber;
- Incidence and estimation of damage to mulberry caused Bihar Hairy Caterpillar;
- Study of life cycle of mulberry leaf webber;
- Study of life cycle of Black Headed Hairy Caterpillar;
- Study of life cycle of mulberry leaf spot;
- Study of life cycle of mulberry leaf rust;
- Study of life cycle of powdery mildew of mulberry;
- Isolation of leaf spot fungus and bacterial blight pathogen in the laboratory and characterization;
- Varietal response of mulberry to root knot nematode disease;
- Incidence, symptoms and damage of Tukra disease on different varieties of mulberry;
- Life cycle of wingless grasshopper and cutworm on mulberry;
- Incidence of thrips on the available varieties of mulberry;
- Collection of specific predators and parasites in mulberry garden, preservation and their classification;
- Diseases and pests associated with mulberry nursery and tree mulberry;
- Commonly used insecticides and fungicides in mulberry garden-classification, forms, formulations and their applications.

VIII. Teaching Methods/ Activities

– Lectures
– Assignments (Reading/ Writing)
– Text Books
– Student presentations
– Experimentation
– Group discussion
– Group work
– Laboratory exercises
– Scientific journals and periodicals/ Publication reviews
– Study visits

IX. Learning outcome

After successful completion of this course, the students are expected be able to:

– Understand the nature of pest and diseases of mulberry, their occurrence, symptoms, damage caused at different stages of the mulberry plant.
– Learn different management practices for pest and diseases in mulberry and use this knowledge for successful mulberry leaf production.

X. Suggested Reading

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Gautam RD. 1994. *Biological Pest Suppression*. Westvill Publishing House, New Delhi.

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Metcalf CL, Flint WP and Metcalf RL. 1962. *Destructive and Useful Insects*. MacGraw-Hill Book Co. Inc., New York and London.

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Nataraju B, Sathyaprasad K, Manjunath D and Aswani Kumar C. 2005. *Silkworm Crop Protection*. Central Silk Board, Bangalore.

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- *Reshme Krishi (Kannada)* – Department of Sericulture, Government of Karnataka, Bangalore.

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I. Course Title : Biotechnology of Mulberry

II. Course code : SER 505

III. Credit Hours : 1+1

IV. Why this course ?

Mulberry is perennial and highly heterozygous crop. Hence, selection in segregating progenies is very difficult. In order to aid the selection in mulberry, the biotechnological tools, viz., Tissue culture techniques, molecular markers and recombinant DNA technology are more useful to aid in selection. Application of these techniques will shorten the breeding procedure. Hence this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of Tissue culture techniques, molecular markers and recombinant DNA technologies to PG students.

The course is organised as follows:

No.	Blocks	Units
1	Mulberry biotechnology, scope and prospects	I Mulberry biotechnology, scope and prospects II Mulberry germplasm characterization III Genotyping and phenotyping
2	Recombinant DNA technology	I Genes transfer systems II QTL mapping III Seri bioinformatics

VI. Theory

BLOCK 1: Mulberry biotechnology, scope and prospects

Unit 1: Mulberry biotechnology, scope and prospects

Scope of breeding for hardier and productive mulberry genotypes. Preservation of genetic material. Development of transgenic mulberry. Molecular linkage map of mulberry. Micropropagation: *In-vitro* propagation in mulberry-production of haploids- induction of haploids, advantages and disadvantages of haploids. Double haploids-induction, advantages and disadvantages of double haploids. Practical achievements of DH method, polyploids- Somaclonal variations, Procedures, advantages, disadvantages and their applications. Secondary metabolites. Gametoclonal variations – their scope and applications. Cryopreservation: Definition and meaning, Steps in cryopreservation, Advantages and disadvantages, Cryopreservation Requirements, applications of cryopreservation in mulberry for germplasm preservation.

Unit 2: Mulberry germplasm characterization

Mulberry germplasm characterization by using molecular markers. Introduction, features of ideal DNA markers, types of DNA markers, uses in crop improvement. Application of biotechnological tools in screening for biotic and abiotic stress tolerance in mulberry.

Unit 3: Genotyping and phenotyping

Introduction, definition of genotype and phenotype. Phenotyping-advantages and disadvantages. Methods of genotyping, advantages and disadvantages of genotyping and applications of genotyping. Marker Aided Selection (MAS) for economically important traits in mulberry. Steps involved in MAS. Application of MAS, advantages of MAS, limitations of MAS.

BLOCK 2: Recombinant DNA technology

Unit 1: Genes transfer systems

Vector mediated gene transfer, microinjection, electroporation, direct DNA uptake, gene gun technique, selectable markers and reporter system; comparison of transgenic technology and traditional breeding methods, detection of transgenic mulberry. Prospects of transgenic mulberry. Procedure of development of transgenic mulberry. Advantages and disadvantages of transgenic mulberry. Risks in transgenic technology. Biosafety and regulatory issues, Achievements.

Unit 2: QTL mapping

Development of maps, Advantages and limitations of QTL mapping. Methods of mapping. Requirements and steps involved in QTL mapping. Mapping populations (F2S and back crosses RILs, NILs, DHs). Tagging of economically important traits in mulberry.

Unit 3: Seri bioinformatics

Bioinformatics in crop improvement-introduction, branches of bioinformatics, computer programmes used in biology, applications in crop improvement, varietal information system, PGR data base. Studies on Genomics- genomics in crop improvement, types of genomics: structural, functional and applications, achievements and limitations. Studies on proteomics. Studies on metabolomics, advantages of bioinformatics, limitations. Intellectual Property Rights. Plant variety protection act (PVPA): introduction, types of protection, basic requirements, organizations involved, procedure of PVP, material to be protected, types of varieties, exemptions under PVPA, advantages and disadvantages of PVPA. Nano- technology: introduction, main features, Application of nano-technology, application in mulberry improvement.

VII. Practicals

- Laboratory safety rules;
- Seri biotechnology lab and its facilities;
- Preparation of MS medium for tissue culture in mulberry;
- Selection, collection and preparation of plant material for mulberry tissue culture;
- Culturing of plant material/explant in culture media;
- Tissue culture techniques for mulberry propagation;
- Hardening of tissue cultured mulberry plants;
- Isolation of genomic DNA- mulberry leaf;
- Isolation of genomic DNA- mulberry leaf;
- Amplification of DNA in mulberry by using PCR;
- Study of diversity of mulberry germplasm by using molecular markers;
- Study of diversity of mulberry germplasm by using molecular markers;
- Comparative study of diversity of mulberry germplasm through morphological traits and molecular markers;
- Techniques for gene transformation in mulberry;
- Techniques for gene transformation in mulberry;
- Molecular databases in mulberry;

- Visit to MAS lab in Department of Biotechnolgy, UAS, GKVK, Bengaluru;
- Visit to Seri-Biotechnology Research Laboratory, CSB, Kodathi, Bengaluru.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text books/ Publication reviews
- Student presentations
- Group work
- Student's interview of key policy makers
- Case analysis and case studies and guest lectures
- Review of policy documents
- Visits

IX. References

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Kendrew J. 1994. *The Encyclopedia of Molecular Biology*. Blackwell Scientific Publications, Oxford.

Old RW and Primrose SB. 1994. *Principles of gene manipulation: An Introduction to genetic engineering*, 5th Ed. *Blackwell Scientific Publications*, U. S. A.

Hansen G and Wright MS. 1999. Recent advances in the transformation of plants. *Trends in Biotech.,* **13:** 324-331.

Vijayan K. 2004. Genetic relationship of Japanese and Indian mulberry (*Morus* spp.) genotypes as revealed by DNA fingerprinting. *Plant Syst. Evol.,***243**: 221-232.

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- www.tnau.ac.in/
- www.csrtimys.res.in/

I. Course Title : Anatomy and Physiology of Sericigenous insects

II. Course Code : SER 507

III. Credit Hours : 1+1

IV. Why this course ?

To understand the basic principles of anatomy, different organs/ systems such as respiratory, circulatory, digestive, nervous and reproductive systems and their functional aspects (physiology) to strengthen the knowledge of students to take up meaningful research studies among sericigenous insects.

V. Aim of the course

This course is designed to provide basic information/ knowledge on anatomy; internal organs/systems, functions and their (physiology) thorough understanding of the sericigenous insects. Silk production among various sericigenous insects, their evolution and differences will also be studied.

The course is organized as follows:

No	Blocks	Units
1.	Anatomy of sericigenous insects	I Introduction, scope and importance II Anatomical studies of different systems III Comparison of anatomical structures among various sericigenous
2.	Physiology of different systems	I Introduction, scope and importance II Physiology of different systems III Silkworm nutrition and synthetic/artificial diets

VI. Theory

BLOCK 1: Anatomy of sericigenous insects

Unit 1: Introduction, scope and importance

Different structures of the various internal systems. The scope of the study for their application aspects and its importance for future research work.

Unit 2: Anatomical studies of various systems

Digestive, circulatory, respiratory, excretory, muscular, reproductive and nervous systems (including central, visceral and peripheral) and sense organs of larva, pupa and adult. Endocrine and exocrine glands (including silkglands).

Unit 3: Comparison of anatomical structures among various sericigenous insects

Variation of anatomical structures in different life stages, viz., larva, pupa and adult among different sericigenous insects mulberry, tasar, eri and muga.

BLOCK 2: Physiology of different systems

Unit 1: Introduction, scope and importance

Relation of structure to function and its application aspects.

Unit 2: Physiology of different systems

Physiology of digestive, circulatory, respiratory, excretory, muscular, reproductive, nervous system and endocrine and exocrine glandular systems, Hormonal mechanism, enzymes, pheromones, nutritional role of vitamins and other growth factors. Properties of haemolymph, histology, nerve impulses, sensory physiology. Silkglands and silk sysnthesis.

Unit 3: Silkworm nutrition and synthetic/artificial diets

Qualitative and quantitative nutritional requirement of silkworms, vitamins, carbohydrates, proteins and role of microbes in nutrition. Preparation of artificial/synthetic diets for silkworms. Endocrinal aspects of silk production.

VII. Practicals

- Study of digestive system of mulberry silkworm and silk moth;
- Study of excretory system of mulberry silkworm and silk moth;
- Study of digestive system of larva of Eri silkworm;
- Study of nervous system and endocrine glandular system mulberry silkworm larvae and Eri silkworm larvae;
- Study of circulatory and reproductive system in mulberry silkworm;
- Study of circulatory and reproductive system in Eri silkworm;
- Study of silk glands in mulberry silkworm, tasar, Eri and muga silkworms;
- Study of properties of haemolymph of mulberry, Eri and tasar silkworms;
- Study of physiology of digestion and excretion of mulberry silkworm;
- Study of physiology of circulatory and nervous system of mulberry silkworm;
- Study of physiology of reproductive system of mulberry silkworm;
- Study of physiology of silk protein synthesis;
- Study of endocrine systems, diapauses and hibernation;
- Preparation of artificial diets/synthetic diets;
- Study of comparative anatomy of digestive system of pupa and adult of mulberry silkworm;
- Study of comparative anatomy of digestive system of pupa and adult of Eri silkworm;
- Detection of frequency of variation in vaorioles in eri moths resulting from larvae fed with different hosts;
- Visit to sericulture institutes.

VIII. Teaching Methods/ Activities

- Lectures
- Dissections, drawing of sketches using camera lucida; grid/ photograph of the system
- Text Books
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals
- Student presentations
- Assignments, practical record maintenance
- Preparation of artificial diets and their application.

IX. Learning outcome

After successful completion of this course the students are expected to be able to – acquire basic knowledge about various systems in sericigenous insects, their structure and function. This will enable the students to thoroughly understand the nutritional requirements and silk production aspects. This will help the students to take up further research work meaningfully.

X. Suggested Reading

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Beck SD. 1963, *Animal Photoperiodism*. Holt, Holt Library of Science Series, New York.

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I. Course Title : Silkworm Biochemistry and Nutrition

II. Course Code : SER 508

III. Credit Hours : 1+1

IV. Why this course ?

The silkworm growth directly depends on the food it consumes, digestion of consumed food to nutrients and assimilation of the digested nutrients into its body and then produce silk cocoons. The present course is designed to make the students understand the nutrients required for normal growth of silkworm and produce quality cocoons.

V. Aim of the course

The post graduate students should have a clear understanding of importance of feeding leaf with suitable nutrients in order to obtain reliable results of experiments conducted with silkworms. The course on silkworm biochemistry and nutrition will aim at enlightening the students on importance of raising silkworm on suitable mulberry leaves that nourish silkworm so as to undoubtedly infer the impact of treatments imposed during the experimentation. Further, they will be competent enough to emphasise on the balanced nutrition to mulberry among the farmers, since it's the sole food for silkworm.

The course is organized as follows:

No.	Blocks	Units
1	Nutrients for silkworm growth	1. Requirement of nutrients to silkworm 2. Metabolism and Utilization of nutrients
2	Biochemistry of nutrient utilization	1. Biochemical pathway for survival and cocoon production

VI. Theory

BLOCK 1: Nutrients for silkworm growth

Unit 1: Requirement of nutrients to silkworm

Carbohydrate, protein and fat metabolism, chemical nature of vitamins and hormones. Nutritional requirements of amino acids, lipids, vitamins, minerals. qualitative and quantitative requirements of nutrients.

Unit 2: Metabolism and Utilization of nutrients

Metabolism of amino acids, lipids, vitamins, minerals, Leaf composition as affecting silkworm growth, feed efficiency, supplementation of nutrients.

BLOCK 2: Biochemistry of nutrient utilization

Unit 1: Biochemical pathway for survival and cocoon production

Physiology of moulting, egg and pupal diapause in silkworm, biochemical pathways of silk synthesis and biochemistry of haemolymph.

VII. Practicals

- Qualitative tests for carbohydrates in silkworm heamolymph;
- Quantitative estimations of total soluble sugars in silkworm heamolymph;
- Qualitative tests for proteins and free amino acids in silkworm heamolymph;
- Quantitative estimations of proteins in silkworm heamolymph;
- Qualitative tests for lipids in silkworm heamolymph;
- Quantitative estimations of lipids in silkworm heamolymph;
- Determination of ascorbic acid level in the mulberry leaves;
- Determination of ascorbic acid level in silkworm heamolymph;
- Study of amylase activity in silkworm haemolymph;
- Study of phosphatase activity in silkworm haemolymph and digestive juice;
- Study of esterase activity in silkworm egg, larval haemolymph and silk glands;
- Qualitative tests for phospholipids and cholesterol in silkworm tissues;
- Quantitative estimation of phospholipids and cholesterol in silkworm tissues;
- Study of food consumption indices in silkworm;
- Estimation of lipid biomass in different silkworm breeds;
- Estimation of silk gland biomass in different silkworm breeds;
- Study of isozymes of different enzymes associated with silk productivity;
- Visit to Seri Bio-technology research laboratory/CSGRC.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the role and requirement of various nutrients in silkworm
- Learn the important biochemical pathways in silkworm that ultimately influence cocoon production.

X. Suggested Reading

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I. Course Title : Biotechnology of Silkworm

II. Course Code : SER 513

III. Credit Hours : 1+1

IV. Why this course ?

Silkworm breeding by conventional methods takes relatively longer time. Combining different desirable traits in to one individual requires breaking linkage between desirable and undesirable traits. Application of biotechnology is essential to achieve early results in silkworm crop improvement.

V. Aim of the course

The course is aimed to provide knowledge on biotechnological methods and their application in silkworm crop improvement. The course will address the available methods and approaches that can be applied in the field of sericulture.

The course is organized as follows:

No	Blocks	Units
1	Biotechnological tools	1. Tissue culture techniques 2. Biotechnological methods
2	Application of biotechnology in silkworm	1. Molecular characterization and mapping 2. Transgenics, Bioinformatics and biosafety

VI. Theory

BLOCK 1: Biotechnological tools

Unit 1: Tissue culture techniques

Development ofpolyploids, gametoclonal variations - their scope and applications. Cryopreservation.

Unit 2: Biotechnological methods

Biotechnology and its scope in silkworm, recombinant DNA technology, genes transfer systems-vector mediated gene transfer, microinjection, electroporation, direct DNA uptake, gene gun technique, selectable markers and reporter system. Molecular markers.

BLOCK 2: Application of biotechnology in silkworm

Unit 1: Molecular characterization and mapping

Mulberry silkworm germplasm characterization by using molecular markers, Development of maps, QTL mapping, MAS for economically important traits in silkworm, Mapping populations (F2S and back crosses RILs, NILs, DHs), Molecular mapping and tagging of economically important traits.

Unit 2: Transgenics, Bioinformatics and biosafety

Transgenic silkworm-prospects, achievements in silkworm. Silkworm as a bioreactor for foreign gene expression, Molecular aspects of silk synthesis. Application of biotechnological tools in screening for biotic and abiotic stress resistance. Biosafety and regulatory issues, Intellectual Property Rights. Seri bioinformatics. Genomics-structural, functional and applications.

VII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work

– Laboratory exercises
– Scientific journals and periodicals

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Understand the different biotechnological methods available in silkworm crop improvement
– Utilise methods and tools for evolving new silkworm breeds with desirable trait combinations

IX. Suggested Reading

Dandin SB and Naik G. 1970. *Biotechnology in Mulberry* (*Morus* spp.) *Crop Improvement: in Plant Biotechnology and Molecular Markers* : 206-216
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- www.csrtimys.res.in/

I. Course Title : Sericulture By-product utilization and Value addition

II. Course Code : SER 516

III. Credit Hours : 1+1

IV. Why this course ?

Sericulture generates a huge quantity of by-products at each stage of sericulture activity such as rearing bed waste, left over mulberry leaves, mulberry twigs, the discarded silk moth, waste egg sheets, pierced cocoons and damaged cocoons, etc. at grainage. And also inturn it possesses a vast entrepreneurship opportunities in silkworm rearing, silk reeling, re-reeling, twisting, winding, weaving, etc. The present course is designed to make the students to understand all these opportunities in seri-by-products utilization and also entrepreneurship development thus making sericulture as one of the most profitable agro-enterprises.

V. Aim of the course

The course is designed with the aim of making the PG students to understand the best utilization of by-products generated at each stage of sericultural activity and their value addition for generating additional income making them good entrepreneurial managers in sericulture by exploring the vast entrepreneurial opportunities to make sericulture as one of the profitable enterprises for sustainable sericulture.

The course is organised as follows:

No.	Blocks	Units
1.	Entrepreneurship in sericulture	1. Entrepreneurship in sericulture and problems. 2. Sericultural entrepreneurship development in different countries.
2.	Entrepreneurship development in different stages	1. Entrepreneurship development during mulberry cultivation
	2.	Entrepreneurship development during egg production and silkworm rearing. 3. Entrepreneurship development during silk reeling and post reeling activities.
3.	Value addition of by-products in sericulture	1. Value addition during host plant cultivation 2. Value addition during silkworm rearing 3. Value addition during silk reeling and post reeling.

VI. Theory

BLOCK 1: Entrepreneurship in sericulture

Unit 1: Entrepreneurship in sericulture and problems

Concept, need, scope, prospects and problems of entrepreneurship in sericulture.

Unit 2: Sericultural entrepreneurship development in different countries

Sericultural entrepreneurial development in India, China, Japan and other sericultural countries.

BLOCK 2: Entrepreneurship development in different stages

Unit 1: Entrepreneurship development during mulberry cultivation

Entrepreneurship development in mulberry cultivation- kisan nursery, composting, vermicomposting, bio-digester, bio gas production, livestock production, fisheries, mushroom cultivation.

Unit 2: Entrepreneurship development during egg production and silkworm rearing

Entrepreneurial development in silkworm-egg production, Chawki rearing centres and cocoon production.

Unit 3: Entrepreneurship development during silk reeling and post reeling activities

Entrepreneurship development in silk reeling – establishment of reeling units, twisting and dying units, weaving units. Entrepreneurship development in manufacture/ production, marketing/ hiring of sericulture material/equipments and seri-inputs.

BLOCK 3: Value addition of by-products in sericulture

Unit 1: Value addition during host plant cultivation

Value addition during host plant cultivation - mulberry as fuel, green manure, fodder, live fencing material, wind breaks. Mulberry fruits and uses in pickle, jam, jelly, beverage/wine preparation. Mulberry as medicine, mulberry in agriculture and sports industry, mulberry in biogas production, mulberry as shade and avenue tree. Processing of mulberry leaves for tea preparation and food products.Medicinal value of mulberry.

Unit 2: Value addition during silkworm rearing

Value addition during silkworm rearing –silkworm litter as livestock feed; as an organic manure, raw material for biogas production, mushroom raising, poultry feed, fish feed, silkworm excreta in cosmetic industry. Silkworm in human consumption.

Unit 3: Value addition during silk reeling and post reeling

Pupal oil extraction and its uses, pupal powder as animal feed and manure. Flimsy cocoons and waste cocoons used as raw material in spun silk industry and quilting purpose. Silkworm pupa in human consumption-commercialized products and locally prepared dishes. Preparation of handicrafts, toys, wall plates, garlands, greeting cards, etc., from waste cocoons. Sericin for medicine, cosmetics, artificial membranes and plastic industry and other uses of silk.

VII. Practicals

- Visit to grainage for collection of waste cocoons including pierced cocoons;
- Visit to Chawki rearing centres and cocoon production centres for collection of different by-products;
- Visit to Silk reeling units, twisting, dying and weaving units for collection of different by-products;
- Preparation of compost, vermi-compost and biodigester from mulberry waste;
- Value addition during host plant cultivation-mulberry as fuel, green manure, fodder, live fencing material, wind breaks;
- Estimation of calorific value of mulberry wood as fuel;
- Mulberry fruits for table purpose and preparation of pickles, juice, jam, jelly, beverage/wine;
- Raising of mulberry saplings from desired genotypes for social forestry, avenue tree and eco-friendly flora;
- Processing of mulberry leaf for the tea preparation;
- Preparation of different food products with mulberry leaf as ingredient;
- Mushroom cultivation using silkworm litter as substrate;
- Value addition during silkworm rearing – silkworm litter as cattle, sheep and goat feed;
- Preparation of mulberry silage along with popular fodders;
- Quantification of biogas production using silkworm waste;
- Pupal oil extraction and pupal powder preparation and nutrient status estimation;
- Preparation of handicrafts, toys, wall plates, garlands, greeting cards, etc. using waste cocoons;

- Estimation of manurial value of compost and vermi-compost derived from mulberry waste;
- Using of silkworm pupae as animal, fishery and poultry feed.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals/ Publication reviews
- Study visits

IX. Learning outcome

After successful completion of this course, the students are expected be able to:

– Understand the entrepreneurship opportunities in sericulture and their problems during different stages of sericulture entrepreneurship
– Importance of value addition and utilization of sericultural by-products in agriculture and allied sectors.
– Non-textile opportunities for seri by-products and their value added products

X. Suggested Reading

Anonymous. 2002. *Silk Weaving*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Anonymous. 2002. *Colours from Nature – Silk Dyeing Using Natural Dyes*. Vol. I and II, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Bernard P Corbman. 1983. *Textiles: Fiber to Fabric*. 6th Edition, Mc. Graw – Hill International Editions, Home Economic Series, Singapore, p. 594.

Charles J Huber. 1929. *The Raw Silk Industry of Japan*. The Silk Association of America, Inc., New York.

Dandin SB and Gupta VP. 2002. *Advances in Indian Sericulture Research*. CSR&TI, Mysore.

Dandin SB, Jayaswal J and Giridhar K. (Eds.). 2003. *Handbook of Sericulture Technologies*. CSB, Bangalore.

Datta RK. 1996. *Global Silk Scenario – 2001. Proceedings of the International Conference on Sericulture – 1994*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Govindan R, Chinnaswamy KP, Krishnaprasad NK and Reddy DNR. 2000. *Non-Mulberry Sericulture, Silk Technology and Sericulture Economics and Extension. Vol. 3– Proceedings of NSTS* – 1999, UAS, Bangalore.

Sinha S. 1990, *The Development of Indian Silk*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Tazima Y. 1978, *The Silkworm: An Important Laboratory Tool*. Kodansha Ltd., Tokyo.

Tripurari Sharan. 1984. *Sericulture and Silk Industry*. Published by Y.K. Sharma, Consortium on Rural Technology, Delhi.

Ullal SR and Narasimhanna MN., 1981. *Handbook of Practical Sericulture*. CSB, Bangalore.

Yasuji Hamamura. 2001. *Silkworm Rearing on Artificial Diet.* Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

Yonemura M and Rama Rao N. 1925, *Handbook of Sericulture*. Mysore Government Branch Press.

Journals

- *Bulletins of Sericultural Experimental Station* – Suginami, Tokyo, Japan.

- *Journal of Sericultural Science of Japan* – Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* – Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* – CSR & TI, Mysore.
- *Journal of Sericulture and Technology* – NASSI, Bangalore.
- *Indian Silk* – Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* - Bhubaneshwar, Orissa.
- *Reshme Krishi* (*Kannada*) – Department of Sericulture, Government of Karnataka, Bangalore.

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in/
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Course Title with Credit Load
Ph.D. (Agri.) in Sericulture

Course Code	Course Title	Credit Hours
	Major courses	
SER 601	Genetics and Breeding of Mulberry - II	1+1
SER 602	Physiology and Nutrition of Mulberry	1+1
SER 604	Physiological and Biochemical Genetics of silkworm	1+1
SER 605	Silkworm Pathology	1+1
SER 606	Integrated Pest Management in Sericulture	1+1
	Research and publications ethics	1+1
		6+6=12
	Minor courses*	
SER 603	Physiology and Nutrition of silkworm	1+1
SER 607	Sericulture Biotechnology	1+1
SER 608	Silk Technology-II	1+1
SER 609	Seri-Business Management	1+1
		4+4=8

*Note: The students may opt the optional courses from any disciplines/ departments as recommended by the advisory committee of the student based on the research topic.

Major Courses Contents
Ph.D. (Agri.) in Sericulture

I. Course Title : Genetics and Breeding of Mulberry-II

II. Course Code : SER 601

III. Credit Hours : 1+1

IV. Why this course ?

In order to develop high yielding mulberry varieties for different situations, genetic principles and different advanced breeding methods are highly essential. In order to improve mulberry genetically, use of suitable germplasm and conventional methods and non-conventional methods of breeding are useful to meet the current needs. Hence this course.

V. Aim of the course

To make the students to get acquainted with advances in genetics, Cytogenetics and advanced breeding methods for mulberry improvement.

This course is organised as follows:

No.	Blocks	Units
1	Origin and distribution of mulberry, germplasm and biometrical techniques	1. Origin and exploitation of the genus *Morus* 2. Conservation and maintenance of mulberry germplasm 3. Biometrical Techniques in Breeding
2	Conventional and non-conventional breeding methods for mulberry improvement	1. Conventional methods of mulberry breeding 2. Non- conventional methods of breeding 3. Biotechnological approaches for mulberry improvement

VI. Theory

BLOCK 1: Origin and distribution of mulberry, germplasm and biometrical techniques

Unit 1: Origin and exploitation of the genus *Morus*

Origin and exploitation of the genus *Morus*. Species of mulberry and their distribution. Wild species and local genotypes and their importance. A critical appraisal of taxonomy of genus *Morus*. Mode of reproduction in relation to breeding methods in mulberry and genetic constitution. Recent advances in cytology of mulberry. Karyomorphological studies, mitotic and meiotic studies. Recent advances in embryological studies. Study of different ploidy levels of mulberry.

Unit 2: Conservation and maintenance of mulberry germplasm

Different types mulberry conservation. Role of mulberry germplasm in mulberry improvement. Characterization and evaluation of mulberry germplasm for morphological, anatomical, physiological, reproductive, biochemical and molecular traits. Evaluation of commercially released varieties/ genotypes for different growth and yield parameters. Utilization of mulberry gene bank. National and international institutes involved in mulberry germplasm conservation.

Unit 3: Biometrical Techniques in Breeding

Introduction, Assessment of variability: simple measures of variability, Components of variance -Genetic diversity. Aids of selection: Correlation coefficient analysis, Path analysis-Discriminant function. Choice of Parents and Breeding procedures: Partial diallel analysis, Line x Tester analysis - Biparental cross analysis. Varietal adaptation:Components of adaptability, Assessment of stability.

BLOCK 2: Conventional and non-conventional breeding methods for mulberry improvement

Unit 1: Conventional methods of mulberry breeding

Procedures followed for different methods of conventional breeding-Introduction, mass selection and clonal selection. Handling of segregating progenies-pedigree selection and back cross method of selection. Exploitation of heterosis, different kinds of heterosis, estimation of heterosis in mulberry. Three tier system of evaluation of mulberry. Advances in conventional methods of breeding. Poly cross hybrids – Principles involved, advantages and dis advantages. Steps in development of polycross hybrids. Advanced generation breeding. Preliminary yield evaluation, multilocational trial and mulberry authorization for evaluation. Steps for orderly distribution of improved varieties. Release of new varieties. Multiplication system and distribution- Kisan nursery-important varieties developed in conventional method.

Unit 2. Non-conventional methods of breeding

Present status of mulberry varietal improvement through mutation. Importance of induced mutation, recent achievements in mulberry mutation breeding. Limitations of mutation breeding.

Polyploidy, induction of polyploidy in mulberry, special features of triploids in mulberry, process of triploid mulberry development, varieties developed by polyploidy breeding in mulberry. Breeding methods followed for leaf quality parameters, biotic and abiotic stress. Breeding strategies for climate change. Participatory plant breeding (PPB) – introduction, types, stages of participation, objectives, advantages of PPB, role of farmers in PPB.

Unit 3: Biotechnological approaches for mulberry improvement

Recent advances in application of plant tissue culture. Applications of molecular markers in mulberry improvement. Genome characterization.

Development of transgenic mulberry – procedure. Nanotechnology: introduction, main features and its applications. Plant Variety Protection Act (PVPA) – Introduction, types of protection, basic requirements, organizations, procedure, material to be protected, types of varieties, exemptions under PVPA, advantages and disadvantages of PVPA. Statistical approaches for yield tests in mulberry: Field plot techniques in mulberry breeding experiments. Different experimental designs-RCBD, Augmented Randomized Complete Block Design (ARCBD) and LSD.

VII. Practicals

- Geographic distribution of the genus *Morus,* using maps;
- Evaluation of mulberry germplasm maintained at the Department of Sericulture, UAS, GKVK, Bengaluru;
- Study of diversity of mulberry germplasm maintained at the Department of Sericulture, UAS, GKVK, Bengaluru;
- Collection and categorization of available mulberry germplasm using standard key;
- Studies on conservation and maintenance of mulberry Gene bank;
- Identification of suitable mulberry genotypes for tree mulberry;
- Characterization of suitable mulberry genotypes and quality parameters for chawki silkworm;
- Characterization of suitable mulberry genotypes and quality parameters for late age silkworm;
- Identification of suitable mulberry genotypes for fruit purpose;
- Evaluation of commercially released mulberry varieties for growth and yield parameters;
- Phenotypic evaluation of commercially released mulberry varieties;
- Hands on training in callusing, sub-culturing,root initiation, shoot initiation and hardening of tissue culture plants, Triploids, etc.;
- Active bud treatment for polyploid induction in mulberry;
- Layout of field experiments in mulberry;
- Testing for resistance to biotic stresses;
- Testing for resistance to abiotic stresses;
- Selective breeding using marker assisted selection for identifying WUE mulberry genotypes;
- Visit to CSGRC Hosur/ CSB.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussions
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to:

- Know the importance of maintenance of indigenous and exotic lines of mulberry germplasm and their best exploitation in elite mulberry breeding
- Have Knowledge on different methods of breeding technology of mulberry for practical utilization
- Acquire knowledge on breeding of mulberry for various uses, viz., young silkworm rearing, late age silkworm rearing, production of mulberry fruits and raising of tree mulberry.

X. Suggested Reading

Chakraborti SP, Roy Chowddhuri S and Bindroo BB. 2013. *A text book on mulberry breeding and genetics*. Kalyani publications, New Delhi.

Dandin SB. 1986. Mulberry breeding for tropics, In "*Lectures on Sericulture".Suriamya Publishers*, Bangalore, pp. 25-28.

Das BC and Krishnaswami S. 1969. "Estimation of components of variation of leaf yield and its traits in mulberry". *J. Seric.,* **9**(1): 26-30.

Jalaja KS and Ram Rao DM. 2008. "Characterization of seven mulberry genotypes for their leaf quality and bioassay with silkworm", *Bombyx mori* L. *Sericologia*, **48**(1):85-93.

Sarkar A, Chatterjee KK and Das BC. 1988. An easy and dependable method for strain selection in mulberry. *Sericologia*, **28**(2): 233-235.

Journals

- *Indian Journal of Sericulture*, Central Silk Board, Bangalore
- *Indian Silk*, Central Silk Board, Bangalore
- *Seridoc*, Central Silk Board, Bangalore
- *Journal of Sericultural Science Japan*, Japan
- *Korean Journal of Sericultural sciences*
- *Sericologia*, International Sericultural Commission, India
- *Bulletin of Indian Academy of Sericulture*

Websites

- www.csb.gov.in/
- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in
- www.csrtimys.res.in/

I. Course Title : Physiology and Nutrition of Mulberry

II. Course code : SER 602

III. Credit Hours : 1+1

IV. Why this course ?

Mulberry is a deep-rooted crop, draws its nourishment from different layers of the soil. Soil is the store house of water and nutrients which balances the vegetative and physiological growth. The physiological growth is more influenced by photosynthetic capacity, water transport system, absorption pattern of nutrients and carbohydrate metabolism in mulberry. Thus, having knowledge on the above vegetative and physiological growth will certainly help the students to acquire technical competency on above aspects. Hence this course.

V. Aim of the course

The main aim of this course is to provide both physiological and nutritional management through different metabolism. Further, it also helps in understanding different nutritional requirement for different growth stages which is required for silkworm growth and development. In addition, the factors affecting absorption of nutrients and water, pathway of minerals, transpiration, photosynthesis, C4 pathway, cellular respiration, biotic and abiotic stress operating in mulberry will also be learnt. The principles of above and factors influencing them enhance the quality parameters of mulberry which is the need of the hour. The beneficial effect of all the mechanisms help to understand the phenology of mulberry. The academic knowledge on the above help in strengthening the skill of the students to serve the farming community effectively who are involved in quality leaf production and success of sericulture.

This course is organised as follows

No.	Blocks	Units
1	Mulberry Physiology	1. Factors affecting sprouting and establishment of cuttings, role of aeroponics 2. Role of hormones in bud sprouting and rooting of cuttings
2	Growth and development of mulberry	1. Vegetative growth and development of mulberry
3	Plant growth hormones	1. Plant growth hormones and growth regulators
4	Photoperiodism and thermoperiodism	1. Photosynthesis in mulberry 2. Respiration in mulberry
5	Water and nutrient absorption mechanism	1. Soil properties, nutrient uptake and growth of mulberry 2. Soil fertility and INM in mulberry 3. Role of water in mulberry physiology
6	Dormancy, abiotic and biotic stress in mulberry	1. Dormancy in mulberry buds and seeds 2. Biotic and abiotic stress in mulberry
7	Nutrient deficiency symptoms	1. Deficiency symptoms of major nutrients 2. Deficiency symptoms of secondary and micro nutrients

VI. Theory

BLOCK 1: Mulberry Physiology

Unit 1: Factors affecting sprouting and establishment of cuttings, role of aeroponics.

Factors affecting sprouting and establishment of cuttings, Effect of temperature, cold, frost, light and salt. Aeroponics in mulberry. Possibility of deploying aeroponics in rooting and establishment of mulberry.

Unit 2: Role of hormones in bud sprouting and rooting of cuttings

Role of hormones in bud sprouting and rooting of cuttings and other physical agents like temperature, RH, light and water.

BLOCK 2: Growth and development of mulberry

Unit 1: Vegetative growth and development of mulberry

Duration of vegetative period, leaf area development, phases of development in different age groups of plants (Bush and tree type).

BLOCK 3: Plant growth hormones

Unit 1: Plant growth hormones and growth regulators

Plant growth hormones and growth regulators, classification, nature and biosynthesis in different aged plants and their functions.

BLOCK 4: Photoperiodism and thermoperiodism

Unit 1: Photosynthesis in mulberry

Photosynthesis in mulberry. Factors affecting photosynthesis, light and dark reaction, stages of photosynthesis, Calvin cycle, C-4 pathway and productivity.

Unit 2: Respiration in mulberry

Respiration – Cellular respiration, glycolysis, fermentation, citric acid cycle. Transpiration – role of environmental factors affecting transpiration, role of flowering, fruit set and seed development.

BLOCK 5: Water and nutrient absorption mechanism

Unit 1: Soil properties, nutrient uptake and growth of mulberry

Role of physical and chemical properties of soil on nutrient uptake and growth. Absorption pattern of major and micro nutrients in different soils.

Unit 2: Soil fertility and INM in mulberry

Response of mulberry varieties on absorption pattern of N, P, K and micronutrients. Status of various nutrients and soil fertility status and INM principles.

Unit 3: Role of water in mulberry physiology

Functions of water ecophysiology of plant, absorption of water, Passive absorption and Active absorption, pathway of minerals, root pressure.

BLOCK 6: Dormancy, abiotic and biotic stress in mulberry

Unit 1: Dormancy in mulberry buds and seeds

Viability of buds and seeds, concept of plant stress, biotic and abiotic stress, water deficit stress on mulberry,

Unit 2: Biotic and abiotic stress in mulberry

Effect of temperature, cold, frost, light and salt on mulberry growth and development.

BLOCK 7: Nutrient deficiency symptoms

Unit 1: Deficiency symptoms of major nutrients

Deficiency symptoms of N, P and K, toxicity of these nutrients in mulberry plants and their effect on quality of mulberry, reclamation of the soils by soil application, foliar application and fertigation methods.

Unit 2: Deficiency symptoms of secondary and micro nutrients

Key deficiency symptoms of S, Mn, Fe, Mo, Mg, Ca, Zn and other micronutrients and toxicity of these nutrients in mulberry plants and their effect on quality of mulberry, reclamation by soil and foliar application and fertigation methods.

VII. Practicals

- Study of sprouting and rooting in different varieties of mulberry;
- Use of different concentrations of plant growth hormones for establishment of mulberry;
- Study of root parameters in establishment of mulberry;
- Study of transpiration and photosynthesis in mulberry;
- Study of leaf area measurement of different varieties of mulberry;
- Study of different nutrients and their effect on growth and development of mulberry;
- Study of deficiency symptoms of NPK in mulberry;
- Study of mulberry seed viability tests;
- Study of biochemical and mineral composition of leading mulberry varieties;
- Study of absorption patterns of different fertilizers in mulberry;
- Study of different deficiency symptoms in mulberry;
- Study of respiration in mulberry;
- Evaluation of popular mulberry genotypes for biotic and abiotic stresses;
- Effect of various proportions of soil amendments on growth and development of mulberry;
- Study of deficiency symptoms of secondary and micro nutrients in mulberry through pot culture;
- Study of aeroponics in mulberry;
- Visit to aeroponic units at Department of Crop Physiology, UAS, GKVK, Bengaluru;
- Visit to NCBS laboratories, GKVK, Bengaluru.

VIII. Teaching Methods/ Activities

– Lectures
– Assignments (Reading/ Writing)
– Text Books
– Student presentations
– Experimentation
– Group discussions
– Group work
– Laboratory exercises
– Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to:

- Acquire more information on both physiology and agronomic practices to be adopted in rain fed and irrigated mulberry garden.
- The student can utilize better techniques developed for both manure and fertilizer application.
- To gain understanding of different pathways of mulberry which will be helpful for water and nutrient management.

X. Suggested Reading

Bongale UD. 2003. "Nutritional Management and quality improvement in sericulture", *Proceedings of the National seminar on mulberry sericulture research in India* (26 th to 28th November 2001), P-1037.

Dandin SB and Giridhar K. 2014. *Handbook of sericuilture technologies*, CSB, Bengaluru, p.427

Ganga G. 2003. *Comprehensive Sericulture. Volume 2*. Silkworm Rearing and Silk Reeling. Oxford & IBH, New Delhi, p. 429.

Nutritional Management and Quality improvement in sericulture. 2003. KSSRDI. Banglore.

Rajanna L, Das PK, Ravindran S, Bhogesha K, Mishra RK, Singhvi NR, Katiyar RS and Jayaram H. 2005. *Mulberry cultivation and physiology,* Central Silk Board, Bangalore, p. 367.

Rangaswamy G, Narasimhanna MN, Kasiviswanathan K and Sastry CR. 1976. *Manual on Sericulture-I.Mulberry cultivation*, FAO, Rome, p.150.

Journals

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- *Journal of Sericultural Science Japan*, Japan
- *Korean Journal of Sericultural sciences*
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I. Course Title : Physiological and Biochemical Genetics of Silkworm

II. Course Code : SER 604

III. Credit Hours : 1+1

IV. Why this course ?

Silk production is affected by both the environment and the genetic background of silkworm. The development of silkworm during its larval stage is crucial in obtaining quality cocoon yield. Understanding the genetic mechanism involved in various physiological and biochemical traits, which inturn influences the cocoon yield is essential in planning silkworm breeding strategies.

V. Aim of the course

The course in designed to make the students realize that silkworm development is influenced by the various physiological processes which are in turn governed by specific genes. Finally the student learns the relationship between these processes, the biochemical pathways and the genes that influence these processes and pathways.

The course is organized as follows:

No	Blocks	Units
1	Developmental Genetics	1. Embryonic development 2. Post-embryonic development
2	Physiological genetics	1. Genetics of Physiology in silkworm 2. Biochemical genetics in silkworm

VI. Theory

BLOCK 1: Developmental Genetics

Unit 1: Embryonic development

Embryonic development of non-hibernating and hibernating eggs; parthenogenesis; development of embryos under special genetic conditions, i.e., controlled by E- group allele**,** NC gene, NI-gene.

Unit 2: Post-embryonic development

Induction and translocation of quantitative and qualitative traits in silkworm. Quantitative traits affected by maturity genes, influence of environmental conditions on the expression of quantitative characters. Inheritance of moultinism, voltinsim and juvenility.

BLOCK 2: Physiological genetics

Unit 1: Genetics of Physiology in silkworm

Genetic control of hormonal mechanism. Role of voltinism genes on determination of quantitative characters. Maternal inheritance and its biochemical aspects. Genetic analysis of cocoon colours; physiology of pigments, genetic relation in terms of pigment permeability and transmission.

Unit 2: Biochemical genetics in silkworm

Genetic basis of enzymes – amylase – esterase – alkaline phosphatase – acid phosphatase – proteins and blood cells – haemocytes – ultrastructure of silkprotein synthesis – glutinous protein of the mucous gland. Importance of developmental, physiological and biochemical genetics in silkworm management, nutrition and breeding.

VII. Practicals

- Silkworm embryo testing and preparation of slides;
- Embryonic development in non – diapausing eggs;
- Embryonic development in diapausing eggs;
- Linkage maps and regional differentiation of the chromosomes;
- Induction of parthenogenesis in silkworm, *Bombyx mori* L.;
- Maternal inheritance in mulberry silkworm;
- Inheritance of voltinism and moultinism in silkworm;
- Maternal inheritance and biochemical aspects;
- Genetics of cocoon colours in *Bombyx mori* L.;
- Sex determination in mulberry silkworm;
- e-group alleles as a tool of developmental genetics;
- Silkworm nutrition in relation to breeding;
- Preparation of artificial diets for mulberry silkworm, *Bombyx mori* L.;
- Biochemical genetics: genetic basis of enzymes;
- Estimation of amylase activity in different races of silkworm;
- Determination of nad-dependent sorbitol dehydrogenase activity in the diapausing eggs of *Bombyx mori* L.;
- Assessment of environmental influence on expression of quantitative traits;
- Study of induction of polyploidy in silkworm.

VIII. Teaching Methods/ Activities

- – Lectures
- – Assignments (Reading/Writing)
- – Text Books
- – Student presentations
- – Experimentation
- – Group discussions
- – Group work
- – Laboratory exercises
- - Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- – Appreciate the genetic background that influences the development of silkworm by governing the physiological and biochemical processes
- – Learn the mode of action of silkworm of decisive genes that are critical in silkworm development

X. Suggested Reading

Anonymous 1993. *Principles and Techniques of Silkworm Breeding*. ESCAP, UN, New York. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. P.111.

Gardner EJ, Simmons MJ and Snustad DP. 1991. *Principles of Genetics,* John Willey& Sons Inc., New York. P. 649.

Hiratsuka E. 1999. *Silkworm Breeding*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. P. 500.

Jolly MS, Sen SK, Sonwalker TN and Prasad GK. 1979. *Non-mulberry Silks*. FAO - Agricultural Service Bulletin, Rome. P. 178.

Kovalev PA. 1970. *Silkworm Breeding Stocks*. Central Silk Board, Bombay. P. 233.

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Singh RK and Chaudhary BD. 1996. *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers, New Delhi. P. 318.

Sreeramareddy G. 1998. *Silkworm Breeding*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. P.

Tazima Y. 1964. *The Genetics of Silkworm*. Logos Press Ltd., London. P. 253.

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- www.tnau.ac.in
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I. Course Title : Silkworm Pathology

II. Course Code : SER 605

III. Credit Hours : 1 +1

IV. Why this course ?

It is well-known that silkworm diseases are posing a threat in silk cocoon production thereby causing severe losses to the silkworm rearers. Silkworm diseases are estimated to cause a loss of 20 to 40% cocoon production. In addition, the quality of the cocoons produced also gets deteriorated affecting the economy of the cocoon rearers. Thus having detailed knowledge on the silkworm diseases with regard to various aspects will certainly help to produce competent technical man power. Hence is this course.

V. Aim of the course

The course is structured to provide both basic and applied knowledge on the viral, bacterial, protozoan and fungal diseases of silkworm as well as their prevention and control procedures. The course aims to provide the students the knowledge to diagnose and identify the different infections, knowledge on the etiological agents, their interactions, etc. This certainly helps the students to equip them with basic and applied information with respect to various pathogens and their prevention so that it helps them in strengthening their academic knowledge and also to serve the farming community effectively.

The course is organised as follows:

No	Blocks	Units
1.	Viral diseases of silkworm	1. Viral diseases of silkworm 2. Prevention and control of viral diseases of silkworm
2.	Bacterial diseases of silkworm	1. Importance of bacterial diseases of silkworm 2. Bacterial diseases- symptomatology, prevention and control
3.	Protozoan and fungal diseases of silkworm	1. Protozoan diseases, pathogens, symptomatology, prevention and control 2. Fungal diseases, pathogens, symptomatology, prevention and control

VI. Theory

BLOCK 1: Viral diseases of silkworm

Unit 1: Virus diseases of silkworm

Introduction to silkworm virus diseases. Symptomatology and basic knowledge on them. Economic importance, classification of silkworm viruses. Symptomatology and diagnosis of viral infections of silkworm. Purification of viruses and serological techniques. Nature, size and morphology of nuclear polyhedrosis virus, cytoplasmic polyhedrosis virus, infectious flacherie virus, densonucleosis virus.

Unit 2: Prevention and control of viral diseases of silkworms

Predisposing factors, disease cycle including replications, other hosts and spread of virus diseases. Interaction among silkworm viruses. Histopathology and pathophysiology of viral infections. Prevention and control.

BLOCK 2: Bacterial diseases of silkworm

Unit 1: Importance of bacterial diseases of silkworm

Introduction, history and importance ofBacterial diseases of the silkworm. Mixed infections. Etiology of bacterial flacherie, morphology and chemistry, pathogenicity, route of infection, silkworm immunity and serological detection.

Unit 2: Bacterial diseases- symptomatology, prevention and control

Introduction, bacterial septicemia, bacterial diseases of digestive organs. History and importance ofBacterial toxicosis of the silkworm. Structure and chemistry, biosynthesis of protein and chemistry of crystal toxin, histopathology, pathophysiology, Prevention and control.

BLOCK 3: Protozoan and fungal diseases of silkworm

Unit 1: Protozoan diseases, pathogens, symptomatology, prevention and control

Introduction, history and importance of the pathogenic protozoans of silkworms. Biodiversity, isolation, purification, morphology and chemistry of pathogenic protozoans. Strains of Microsporidians infecting silkworm and their life-cycle. Symptoms at the various stages of the life cycle of silkworm, pathologies, routes of infection, alternative hosts, cross infectivity, survival and spread, detection, prevention and control.

Unit 2: Fungal diseases, pathogens, symptomatology, prevention and control.

Introduction to fungal diseases, economic importance and classification of fungal diseases of silkworms, general morphology of Deuteromycetes. Life cycle of the different fungi pathogenic to silkworms-white, green, yellow, black and red muscardines and *Aspergillus* diseases. Predisposing factors, symptomatology, pathology (histopathology and pathophysiology), host range, host susceptibility, prevention and control.

VII. Practicals

- Survey for viral and bacterial diseases of silkworm based on external symptoms;
- Survey for protozoan and fungal diseases of silkworm based on external symptoms;
- Isolation and purification of silkworm viral pathogens;
- Isolation and purification of silkworm bacterial pathogens;
- Staining techniques for silkworm viruses and bacteria;
- Identification of silkworm pathogens based on morphology;
- Infectivity techniques for silkworm diseases;
- Cross infectivity of mulberry lepidopteran pests to silkworm;
- Cross infectivity of pathogens of silkworm pathogens to mulberry lepidopteran pests;
- Purification of pebrine pathogens and hatching of spores;

- *In-vitro* evaluation of chemicals against protozoan and fungal pathogens of silkworm;
- *In vivo* evaluation of effective chemicals against protozoan and fungal pathogens;
- Life cycle studies of important bacterial and fungal pathogens of silkworm;
- Interactions among different silkworm pathogens in silkworm;
- Practising hygienic measures in silkworm rearing for prevention of silkworm diseases;
- Practising shoot rearing method with net method of bed cleaning for prevention of silkworm diseases;
- Application of bed disinfectants against different diseases of silkworm;
- Application of room disinfectants to eliminate silkworm pathogens;
- Visit to Silkworm Pathology laboratory of CSB and State Sericulture Institute.

VIII. Teaching Methods/Activities

– Lectures
– Assignments (Reading/ Writing)
– Text Books
– Students' presentations
– Experimentation
– Group discussions
– Group work
– Laboratory exercises
– Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to be able to.

- Conduct survey for the diseases of silkworm, their diagnosis and identification
- Utilize the culturing and staining techniques for silkworm pathogens
- Prevention and control successfully the silkworm diseases so as to enable the farmers to successfully produce cocoon crops.

X. Suggested Reading

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Aruga H and Tanada Y. 1971. *The Cytoplsmic polyhedrosis virus of silkworm*. Univ.TOKYO press, TOKYO, p.234.

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- *Journal of Sericultural Science Japan*, Japan
- *Korean Journal of Sericultural sciences*
- *Sericologia*, International Sericultural Commission, India.
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I. Course Title : Integrated Pest Management in Sericulture

II. Course Code : SER 606

III. Credit Hours : 1+1

IV. Why this course ?

Suppression of Pests of mulberry and non-mulberry silkworm food plants as well as pests of silkworms by deploying the chemical pesticides is known to be non-environmental friendly and induces resistance among pests causing pest outbreaks. The same is deleterious for silkworms, thus resulting in cocoon crop losses. Hence, it is always advisable to make use of the available methods of prevention and suppression methods in suitable combination ie., integrated management of pests so as to keep their populations below the economic injury level for successful cocoon crop production. The above knowledge among Ph.D students is essential and hence this courses assumes importance.

V. Aim of the course

The course is structured to improve knowledge on pests, factors affecting their biotic potential, damage caused, bio-ecology and integrated managements of pests of mulberry and non-mulberry silkworm food plants and mulberry as well as non-mulberry silkworms. In addition,the eco-friendly management practices for these pests will also be taught.

The course is organised as under:

No.	Blocks	Units
1	Pest and pest outbreak	1. Pests, classification and Damage 2. Pest outbreaks and pest surveillance and forecasting
2.	Pest management	1. Principles and methods 2. Eco-friendly pest management
3.	Bio-ecology and management	1. Mulberry pests 2. Mulberry silkworm uzifly 3. Grainage pests 4. Pests of non-mulberry silkworm food plants 5. Pests of non-mulberry silkworms

VI. Theory

BLOCK 1: Pest and Pest Outbreak

Unit 1: Pests, classification and damage

Concept of pests, classification of insect pests. Types of damage caused to host plants of silkworms and assessment of extent of damage.

Unit 2: Pest outbreaks and pest surveillance and forecasting

Causes for insects assuming pest status. Factors affecting the natural balance of insects in mulberry eco-system. Pest surveillance and forecasting of outbreaks.

Block 2: Pest Management

Unit 1: Principles and methods concept of pest management

Principles and methods of pest management. Integrated pest management – Meaning, practical utilization and merits.

Unit 2: Eco-friendly pest management

Eco-friendly pest management – concept, incorporation in IPM package, benefits. Development of cultural and mechanical methods, botanicals, other animal derived insecticides and biological control means in IPM.

Block 3: Bio – Ecology And Integrated Management Of Pests

Unit 1: Mulberry Pests

Bio-ecology and IPM of root feeding, steam boring, leaf eating and sap sucking pests of mulberry.

Unit 2: Mulberry silkworm uzifly

Biology of mulberry silkworm uzifly in relation to the biotic and abiotic environment and IPM package for the pest.

Unit 3: Grainage pests

Pests eccountered in mulberry silkworm egg production centres, damage caused and their management.

Unit 4: Pests of non-mulberry silkworm food plants

Incidence and extent of damage caused by pests on castor, terminalia and som. Biology of important defoliators and effect of ecological factors and IPM of important pests.

Unit 5: Pests of non-mulberry silkworms

An account of biology of pests and predators of tropical and temperate tasar silkworms and muga silkworm. Pests of eri silkworm. IPM of *Blepharipa zebra, Canthecona furcellata* and bird predators of tropical tasar.

VII. Practicals

- Survey and collection of insect pests of mulberry and their classification;
- Observations on nature and extent of damage and loss occurred to mulberry;
- Sampling methods for pest surveillance;
- Incidence of termites on different varieties of mulberry;

- Incidence of jassids, black headed hairy caterpillar and leaf folder on mulberry;
- Incidence of white mealy bug on different mulberry varieties;
- Life cycle of black headed hairy caterpillar on mulberry and castor;
- Biology of mulberry leaf webber and its varietal preference and IPM;
- Study of botanical pesticides and bio-agents used in mulberry pest management;
- Study of biological control agents used in mulberry eco-system and uzifly management;
- Forms, formulations and application of pesticides;
- Safety insecticides, their permissible limits and safety periods in mulberry pest management;
- Integrated management of rootknot nematode of mulberry;
- Incidence and biology of uzifly on mulberry silkworm;
- Construction of life table for indian uzifly based on the available data;
- Integrated management of mulberry silkworm uzifly;
- Survey for insect and non-insect pests in mulberry silkworm grainage;
- Study of pests of castor and *Terminalia* spp. and their management;
- Visit to CSGRC, Hosur/ R & D instiutions.

VIII. Teaching Methods/ Activities

- Lectures
- Providing study materials/ lecture materials
- Practical manuals
- Assignments (writing/ reading)
- Text books/ publications/ reviews/ technical bulletins/ manuals/ proceedings of scientific seminars
- Students presentations
- Group discussions
- Visits to silkworm rearing house/ silkworm pathology laboratories

IX. Learning outcome

After undergoing this course the students will acquire knowledge on the concept of pest, damage caused, outbreaks, pest management principles and methods, IPM and eco-friendly measures. In addition, they will have detailed information on the bio-ecology and management of pests encountered in sericulture which certainly helps them for effective advocation to the rearers and graneurs. This inturn ensures sustainability of sericulture.

X. Suggested Reading

Dandin SB, Jayant Jayaswal and Giridhar K. 2003. *Handbook of Sericulture Technologies*. CSB, Bangalore.

Dent DR and Walton MP. 1997. *Methods in Ecological and Agricultural Entomology*. CAB International, Cambridge.

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Huang E. 2003. *Protection of Mulberry Plants*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

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- *Journal of Sericultural Science Japan*, Japan
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Minor Course Contents
Ph.D. (Agri) Sericulture

I. Title : **Physiology and Nutrition of Silkworm**

II. Course Code : **SER 603**

III. Credit : **1+1**

IV. Why this course ?

Present Sericulture and allied sectors face tremendous challenges on multiple points, quality silk production, disease management, nutritional and ecological security to silkworms. Researchers, stake holders are benefited with knowledge and skill so as to reduce the risks in silk production.

V. Aim of the course

The course is designed to provide both basic and applied knowledge to avoid risks in silkworm rearing. It aims to equip students to indentify, evaluate and evolve ways to address risks in silkworm rearing, quality silk production and to evolve artificial nutritional diets for silkworms.

The course is organized as follows:

No	Blocks	Units
1.	Importance and scope	1. Importance of physiology
2.	Physiological studies	1. Physiology of digestion and excretion
		2. Physiology of circulation and respiration
		3. Physiology of endocrine system, egg diapauses and its role in growth and development
		4. Physiology of silk synthesis.
		5. Nutrition of silkworms
3.	Applied aspect of physiological	1. Hormone and enzyme applications
		2. Preparation of artificial diets for productivity of silk

VI. Theory

BLOCK 1: Importance and Scope

Unit 1: Importance of physiology

Study the importance, progress in developed countries Japan, China, Korea and the importance in India.

Unit 2: Study the scope and development of physiological studies and its applications in sericulturally advanced countries

BLOCK 2: Physiological studies

Unit 1: Physiology of digestion and excretion

Physiology of digestion and excretion enzymes, metabolism and various nutrients carbohydrates, proteins amino acids, vitamins, minerals excretory physiology, water conservation and utilization in the body.

Unit 2: Physiology of circulation and respiration

Physiology of circulation and respiration. Haemolymph its composition various cells in haemolymph phagocytes, leucocytes, etc. amylase, synthesis of blood role of enzymes and hormones on circulation. Physiology of respiration, O_2 supplementation, purification of haemolymph.

Unit 3: Physiology of endocrine system, egg diapauses and its role in growth and development

Physiology of endocrine system, Brain hormone, prothoracic gland hormone, corpora allata, corpora cardiac, sub-oesophageal glands, growth and development, moulting, diapauses prio synthesis of pheromones and their role in regulating silkworm behaviour. PTTH, JH analogues physiology of moulting and spinning.

Unit 4: Physiology of silk synthesis

Physiology of silk synthesis, Prio synthesis and fibroin sericin role of lyonet/ pilippis gland, Molecular basis of silk protein synthesis, sericin and fibroin.

Unit 5: Nutrition of silkworms

Utilizing of mulberry leaves, nutritional requirements of silkworms, digestion and utilization of various nutrients digestive enzymes, metabolism of various kinds of nutrients, carbohydrates, proteins, amino acids, vitamins and minerals.

BLOCK 3: Applied aspect of physiological studies:

Unit 1: Hormone and enzyme applications

Hormone and enzyme application tricontinol, serimore, sampoorna JH analogues, moulting hormones.

Unit 2: Preparation of artificial diets for productivity of silk

Preparation of artificial clients for silk productivity. Diets with mulberry composition, diet without mulberry and classification of diets. Nutrient supplementation.

VII. Practicals

- Study of consumption indices of carbohydrates utilization;
- Study of consumption indices of proteins and lipids utilization;
- Study of amylase activity in digestive juice of different breads of silkworm;
- Study of esterese activity in egg, haemolymph and silkglands of different breads of silkworm;
- Study of acid phosphatase activity in haemolymph and alkaline phosphatase digestive juice of different breads of silkworm;
- Determination of free amino acids in the haemolymph of silkworm;
- Determination of trehlose content in the haemolymph of silkworm;
- Application of hormones on growth and development of silkworms;
- Testing of plant products for growth and productivity in silkworm;

- Application of JH analogues and study its influence on growth and development of mulberry silkworm;
- Application of MH analogues and study of its influence on growth and development of mulberry silkworm;
- Determination of NAD-dependent sorbitol dehydrogenase activity during egg diapause;
- Nutrition supplementation through leaf fortification and its studies on growth and development;
- Preparation of artificial diets with mulberry component;
- Preparation of artificial diets (synthetic) without mulberry components;
- Visit to CSTRI/ NSSO;
- Visit to SERICARE/ Crop Physiology lab;
- Visit to SRBL Kodathi, Karnataka.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to be able to

- Understand the basic aspects of physiological studies to apply it for research work in P.G.
- Learning to establish skills and tools of physiological studies to apply on growth and development of silkworms and silk productivity.
- Utilize the knowledge for its application of entrepreneur development for production of products related to growth and development of silkworm and silk productivity and quality.

X. Suggested Reading

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Giese AC. 1973. *Cell Physiology*. 4th Edn., Philadelphia, Saunders.

Gilmour D. 1961. *Biochemistry of Insects*. Academic Press, New York.

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Govindan Bhaskaran, Stanley Friedman and Rodriguez JG. 1981. *Current Tropics in Insect Endocrinology and Nutrition*. Plenum Press, New York and London.

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Sturnikov VA. 1976. *Control of Silkworm Development and Sex*. MIR Publishers, Moscow.
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I. Course Title : Sericulture Biotechnology

II. Course Code : SER 607

III. Credit Hours : +1

IV. Why this course ?

Hybridization and selection in segregating progenies of mulberry are very difficult because of its heterozygosity. In order to aid the selection in mulberry, biotechnological tools, viz., Tissue culture techniques, molecular markers and recombinant DNA technology are more useful to aid in selection. Application of these techniques will shorten the breeding procedure. Hence this course.

V. Aim of the course

The course is designed to equip the PG students with recent developments in the field of Tissue culture techniques, molecular markers, mapping and sequencing and recombinant DNA technologies applied both in mulberry and silkworm improvement.

The course is organised as follows:

No.	Blocks	Units
1	Biotechnology in Sericulture	1. Perspective, scope and current status of biotechnology in Sericulture 2. Mapping and sequencing of mulberry and silkworm
2	Tissue culture and Recombinant DNA techniques	1. Tissue culture in mulberry 2. Recombinant DNA techniques in mulberry and silkworm 3. Seri bioinformatics

VI. Theory

BLOCK 1: Biotechnology in sericulture

Unit 1: Perspective, scope and current status of biotechnology in Sericulture

Perspective, scope and current status of biotechnology. Techniques adopted in Restricted Fragment Length Polymorphism (RFLP), Random Amplified Polymorphic DNA (RAPD),Amplified Fragment Length Polymorphism (AFLP) and Simple Sequence Repeats (SSR). Applications of PCR (Polymerase chain reaction) and agarose gel electrophoresis.

Unit 2: Mapping and sequencing of mulberry and silkworm

Mapping and sequencing of mulberry and silkworm. Genome of mulberry and silkworm. Molecular basis for improvement of yield components in mulberry and silkworm.

BLOCK 2: Tissue culture and Recombinant DNA techniques

Unit 1: Tissue culture in mulberry

Micro propagation in mulberry, Production of haploids and Double haploids (DH) lines, Synthetic seeds, Induction of *in-vitro* flowering, *In-vitro* screening of mulberry for different stress conditions. Somaclonal and Gametoclonal variations - their scope and applications.Cryopreservation in mulberry for germplasm preservation. Protoplast culture and somatic hybridization.

Unit 2: Recombinant DNA techniques in mulberry and silkworm

Recombinant DNA techniques in mulberry and silkworm. Role of agents and microorganisms with emphasis to common vectors for gene transfer. Stability and expression of transferred genes in mulberry and silkworm. Germline transformation and scope of genetic manipulation between silkworm breeds. Application of molecular techniques in gene identification for further breeding programmes. Application of site directed mutagenesis, gene targeting and gene therapy. Silkgland genetics.

Units 3: Seri bioinformatics

Seri bioinformatics- introduction, branches of bioinformatics, computer programmes used. application in crop improvement. Studies on Genomics- genomics in crop improvement, types of genomics: structural, functional and applications, achievements and limitations. Studies on proteomics, Metabolomics. Nano technology- introduction, main features, Application of nano technology in mulberry improvement.

VII. Practical

- RFLP marker technique as applied to mulberry crop;
- RFLP marker technique as applied to silkworm improvement programmes;
- RAPD marker technique as applied to mulberry crop;
- AFLP marker technique as applied to mulberry crop;
- SSR marker technique as applied to mulberry crop;

- Equipments and chemicals used in RFLP and RAPD techniques;
- Equipments and chemicals used in PCR technique;
- Hands on training in mulberry DNA extraction, isolation, purification and concentration;
- Hands on training in silkworm DNA extraction, isolation, purification and concentration;
- DNA quantification and quality assessment in mulberry;
- DNA quantification and quality assessment in silkworm;
- Procedure of Agarose gel electrophoresis;
- Application of PAGE in silkworm;
- PCR reaction; PCR amplification;
- Estimation of genetics distances- cluster analysis in mulberry;
- Estimation of genetics distances- cluster analysis in silkworm;
- Visit to Seribiotech. Lab. of CSB at Kodathi;
- Visit to MAS lab and biotechnology lab of UAS (B);
- Visit to CSR&TI, Mysore- biotechnology division.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books
- Student presentations
- Experimentation
- Group discussion
- Group work
- Laboratory exercises
- Scientific journals and periodicals

IX. Learning outcome

After successful completion of this course the students are expected to be able to

- Utilize the methods and tools of tissue culture and recombinant DNA technologies for mulberry and silkworm improvement.

X. Suggested Reading

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Sambrook J and Russel DW. 2001. *Molecular cloning- A Laboratory Manual* 3rd Ed. *Cold Spring Harbor Laboratory Press. Cold Spring Harbor*, Newyork.

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Hansen G and Wright MS. 1999. "Recent advances in the transformation of plants". *Trends in Biotech.,* **13:** 324-331.

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Chicas A and Macino G. 2011. "Characteristics of post transcriptional gene silencing". *Embo. Reports,* **21:** 992-996.

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- www.csrtimys.res.in/

I. Course Title : Silk Technology-II

II. Course code : SER 608

III. Credit Hours : 1+1

IV. Why this course ?

Next to mulberry silk the other source of natural silk is from non-mulberry sector which is considered to be more profitable in India. Among four commercially exploited silkworm species Tasar, Muga and Eri are having vast diversity and uniqueness in silk quality which provide ancient customary rural employment and remunerative income to huge number of people mainly focusing on tribals. Information on this to students enlightens more on their distribution and characteristic features along with extraction of these silks. Hence this course attains importance.

V. Aim of the course

Non-mulberry sericulture has a glorious heritage. India is the largest user of silk and ranks next to China in global production. Tasar silk industry in India provides rural employment and remunerative income to the tribal population because it requires least investment to get high return. Non-mulberry sericulture has multi-tier earning potential to support rural enterprises/ entrepreneurs, especially in the area of silkworm seed production, commercial cocoon production, Yarn preparation and fabric making besides huge potentials in waste utilization. Therefore, greater emphasis and thrust should be laid on over all development of non-mulberry sericulture. The students after undergoing this course will have the benefit of all recent innovations in reeling technology of Tasar, Muga and spinning technology of Eri and their by-products that will throw light on present scenario of non-mulberry sericulture (Vanya silk) with present facts and figures.

This course is organised as follows

No.	Blocks	Units
1	Scope of non-mulberry sericulture	1. Introduction and spread of non-mulberry sericulture 2. Non-mulberry sericigenous insects
2	Commercially exploited	1. Physical characteristics – Eri, tasar and muga cocoons 2. Commercial characteristics- Eri, tasar and muga cocoons
3	Reeling technology for non-mulberry silk cocoons	1. Reeling technology for non-mulberry silk cocoons
4	Spinning of Eri silk cocoons and By-product utilization	1. Spinning of Eri silk cocoons 2. By-products of non-mulberry silk industry and their utilization
5	Economics of non-mulberry silk reeling unit establishments	1. Organization of non- mulberry silk reeling units
6	Conventional and non- conventional energy, health and environmental hazards	1. Use of conventional and non-conventional energy in silk Reeling industry 2. Health and environmental hazards in silk reeling

VI. Theory

BLOCK 1: Scope of non-mulberry sericulture

Unit 1: Introduction and spread of non-mulberry sericulture

Introduction, spread of non-mulberry sericulture in world and India and its utility to tribal people.

Unit 2: Non-mulberry sericigenous insects

Different non-mulberry sericigenous insects - fagara silk, coan silk and anaphe silk.

BLOCK 2: Commercially exploited non-mulberry silks

Unit 1: Physical characteristics – Eri, tasar and muga cocoons

Cocoon colour, shape, size, compactness, peduncle and ring in respect of Eri, tasar, muga, anaphe, fagara and coan silk cocoons.

Unit 2: Commercial characteristics- Eri, tasar and muga cocoons

Cocoon weight, shell weight, shell percentage, filament length, denier, kakame, non-breakable filament length, reelability, raw silk percentage in respect of Eri, tasar, muga, anaphe, fagara and coan silk cocoons.

BLOCK 3: Reeling technology for non-mulberry silk cocoons

Unit 1: Reeling technology for non-mulberry silk cocoons

Cocoonstifling and cooking methods, brusing, processing, wet and dry reeling of tasar and muga cocoons. Various equipments for reeling-Tevedi, N.R. Das, CTRS imporved reeling machine for tasar cocoon reeling and Choudhari reeling machine for muga silk cocoons, drying and skein making.Semi-automatic reeling machine and Automatic Reeling Meachine. Testing and grading ofnon-mulberry silks.

BLOCK 4: Spinning of Eri silk cocoons and By-product utilization

Unit 1: Spinning of Eri silk cocoons

Definition of spun silk, Various steps involved in spun silk industry (processing, degumming, washing and drying), Eri cocoons as raw material for spun silk industry- spinning of eri cocoons, hand spinning using Natwa, Takli, machine spinning using Amber charaka, madleri charaka and finished products, characteristic features, production of spun silk from pierced tasar and muga cocoons on takli, bhir and N.R. Das spinning wheel.

Unit 2: By-products of non-mulberry silk industry and their utilization

Use of different types of tasar wastes, by-products of tasar reeling - gicha, katia and matka silks. Use of pierced cocoons of tasar and muga, cooking waste, reeling waste and pelade layer. Silk wastes, extraction of pupa oil and its use in various fields. Pupa oil mill.

BLOCK 5: Economics of non-mulberry silk reeling unit establishments

Unit 1: Organization of non- mulberry silk reeling units

Organizational set up of reeling and spinning establishments for tasar, muga and Eri. Site for reeling, facilities for reeling and requirement of human skill and resources for reeling and spinning.Calculation of quantity of cocoons for different reeling and spinning units based on the raw material required for the available appliances. Working out of economics of reeling taking into account the cost of production and returns from resultant raw silk in respect of tasar and muga. Economics of eri spinning.

BLOCK 6: Conventional and non- conventional energy, health and environmental hazards in silk reeling industry

Unit 1: Use of conventional and non-conventional energy in silk Reeling industry

Overview, energy/ wood/ fuel/power consumption in cocoon stifling, cooking and reeling- release of smoke, constituents of smoke – effect of smoke on human health and rearing environment. Effluents from silk production. Solid waste, dust, smoke and effluents from silk weaving factory and spun silk mills.

Unit 2: Health and environmental hazards in silk reeling

Effect of reeling industry on ecosystem. Occupational health risk on reelers/ workers – skin and lungs related problems in reeling units due to release of smoke. Constituents and effect of smoke on human health and environment. Effluents from silk production. Solid waste, dust, smoke and effluents from silk weaving factory and spun silk mills. Policies on pollution control programmes on health hazards – risk and proposed options.

VII. Practicals

- Collection and preservation of non-mulberry silk cocoons in wild;
- Study of biodiversity of non-mulberry silk fauna on different hosts;

- Study of marketing system of cocoon transaction of Tasar;
- Study of marketing system of cocoon transaction of Muga;
- Study of marketing system of cocoon transaction of Eri;
- Study of physical parameters of the Tropical Tasar and Muga cocoons;
- Study of physical parameters of the Eri cocoons;
- Study of physical parameters of Japanese, Chinese and temperate Tasar cocoons;
- Study of commercial parameters of different ecoraces of tropical tasar;
- Study of commercial parameters of Muga and Eri silk cocoons;
- Study of different methods of stifling for Tasar and Muga Cocoons;
- Study of different methods of cooking for Tasar and Muga Cocoons;
- Study of use of enzymes in Tasar cocoon cooking;
- Study of different reeling machinery for Tasar and Muga;
- Study of different spinning appliances for Eri cocoons;
- Visit to spun silk mill to got acquainted with steps of silk spinning;
- Visit to Central Silk Technological Research Institute, Bengaluru;
- Estimation of cost and returns of establishment of reeling units and spun silk unit.

VIII. Teaching Methods/ Activities

– Lectures
– Assignments (Reading/ Writing)
– Text Books/ Publications/ Technical bulletins/ Manuals/ Scientific journals and periodicals
– Student presentations
– Experimentation
– Group discussions
– Group work
– Laboratory exercises

IX. Learning outcome

After undergoing this course the students are exposed to recent reeling techniques adopted in extraction of all non-mulberry silks and the ill effects of reeling industry and it helps in managing both the effluents and smoke and their proper disposal for building up of eco-friendly environment.

X. Suggested Reading

Bhaskar RN and Govindan R. 2005. *Techniques in Silk Reeling*, Department of Sericulture, UAS,GKVK, p. 50.

Ganga G. 2003. *Comprehensive Sericulture.* Volume 2. *Silkworm Rearing and Silk Reeling.* Oxford & IBH, New Delhi, p.429.

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- *Indian Silk*, Central Silk Board, Bangalore
- *Seridoc*, Central Silk Board, Bangalore
- *Journal of Sericultural Science Japan*, Japan
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- *Sericologia*, International Sericultural Commission, India.
- *Bulletin of Indian Academy of Sericulture.*

Websites

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- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in
- www.csrtimys.res.in/

I. Course Title : Seri-Business Management

II. Course Code : SER 609

III. Credit Hours : 1+1

IV. Why this course ?

Sericulture industry possesses a vast opportunity for entrepreneurship at different stages of activities for rural and urban India inturn opening a huge business opportunities, viz., raising saplings in nursery, Grainage, Chawki rearing centre, Silkworm rearing, silk reeling, re-reeling, twisting, doubling and weaving fabric. The present course is designed to make the students to understand the vast entrepreneurship and business management opportunities and risk and non-cash input management associated in sericulture.

V. Aim of the course

The students will know and understand the business opportunities and their management in various activities of sericulture, their constraints, risk management, etc.

The course is organised as follows:

No.	Blocks	Units
1.	Silkworm seed production management	1. Sericulture industry-An overview. 2. Management of silkworm seed production and the associated resources
2.	Leaf production and silkworm rearing programme management	1. Leaf production and supply management, 2. Synchronized silkworm rearing programme management
3.	Silk reeling unit management	1. Management of reeling unit 2. Constraints and risk management

VI. Theory

BLOCK 1: Silkworm seed production management

Unit 1: Sericulture industry-An overview

Sericulture industry – overview, concept and principles of management, personal and resource management.

Unit 2: Management of silkworm seed production and the associated resources

Silkworm seed production management – organizational set up, selection of site, ground plan and establishment of grainage, production planning, raw material, manpower, seed storage programme, marketing, record maintenance; case studies.

BLOCK 2: Leaf production and silkworm rearing programme management

Unit 1: Leaf production and supply management

Quality mulberry leaf production and supply management

Unit 2: Synchronized silkworm rearing programme management

Synchronized silkworm rearing programme – manpower, community rearing, house management, marketing of cocoons.

BLOCK 3: Silk reeling unit management

Unit 1: Management of silk reeling unit

Reeling unit management – organization set up, raw materials- cocoons, fuel, water.

Unit 2: Constraints and risk management

Manpower, procurement skills – constraints, marketing – case studies of charka, cottage basin and filature basin, management of by-products of sericulture – risk management/ non-cash input management.

VII. Practicals

- Study of concept, principals, management and resource management in sericulture;
- Study of organizational set up in Sericultural organizations;
- Producing planning for grainage;
- Raw material management;
- Reeling unit management: man power, raw material, fuel and water;
- Planning for establishment of Chawki Rearing Centre (CRC);
- Planning for establishment of grainage;
- Study of by-products in sericulture;
- Record maintenance in sericulture activities;
- Study of leaf production and supply chain management;
- Risk management/ non cash management in sericulture;
- Visit to grainage and CRC;
- Case study: chawki rearing unit and silk cocoon production;
- Case studies: silkworm seed production unit;
- Case studies: filature and cottage basin units;
- Case studies: Charaka unit, improved Charaka units;
- Visit to seed cocoon markets;
- Visit to silk reeling units.

VIII. Teaching Methods/ Activities

- Lectures
- Assignments (Reading/ Writing)
- Text Books/ Publication reviews
- Class presentations and assignments
- Experimentation
- Group discussion
- Group work
- Laboratory exercises

– Scientific journals and periodicals
– Study visits

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the Business opportunities in sericulture and their constraints and risk management during different activities of sericulture that helps for earning their livelihood.

X. Suggested Reading

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Charles J Huber. 1929. *The Raw Silk Industry of Japan*. The Silk Association of America, Inc., New York.

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Datta RK. 1996. *Global Silk Scenario–2001. Proceedings of the International Conference on Sericulture – 1994.* Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.

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Tripurari Sharan. 1984. *Sericulture and Silk Industry*. Published by Y.K. Sharma, Consortium on Rural Technology, Delhi.

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- *Journal of Sericultural Science of Japan* – Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
- *Sericologia* – Jacques Rousseau, 69350, La Mulatiere, France.
- *Indian Journal of Sericulture* – CSR & TI, Mysore.
- *Journal of Sericulture and Technology* – Published by NASSI, Bangalore.
- *Indian Silk* – Central Silk Board, Bangalore.
- *Bulletin of Indian Academy of Sericulture* – Bhubaneshwar, Orissa.
- *Current Science* – C.V. Raman Institute of Science, Bangalore.
- *Reshme Krishi* (Kannada) – Department of Sericulture, Government of Karnataka, Bangalore.

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- www.karnataka.gov.in/kssrdi/documents/2019/tender%20KC.pdf
- www.tnau.ac.in
- www.csrtimys.res.in

ANNEXURE I

List of BSMA Committee Members for Sericulture

(Silk Worm Host Plant Sciences/Silk Worm Cocoon Production/Silk Worm Improvement/Silk Reeling, Post Reeling Technology and Value Addition)

S.No.	Name and Address	Specialization
1.	**Dr P Venkataravana** **Professor of GPB & Dean (Sericulture)** College of Sericulture, Chintamani-563 125 deanseri@uasbangalore.edu.in; Mob: 09449866914	**Chairman**
2.	**Dr V Shankaranarayan** **Former Dean** PB No. 29, Chintamani-563 125 shankaranarayana@gmail.com; Mob: 09448158763	**Convener**
3.	**Dr Fatima Sadatulla** **Professor & Head** Department of Sericulture, University of Agricultural Sciences,GKVK, Bangalore-560 065 fatimasadatulla@yahoo.com; Mob: 9740056596	**Silk Worm Pest Management**
4.	**Dr RN Bhaskar** **Professor** Department of Sericulture, University of Agricultural Sciences,GKVK, Bangalore-560 065 rnbhaskar@rediffmail.com Mob: 09448359151, 08154290547	**Silk Worm Management and Disease Management**
5.	**Dr Ramakrishna Naika** **Professor** College of Sericulture University of Agricultural, Chintamani-563 125 rnaika@gmail.com; Mob: 09448134789	**Crop Protection and Sericulture**
6.	**Dr Virendra Koul** **Professor & Head** Division of Sericulture Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, J&K-180 009 koulvirendra@gmail.com; Mob: 09419181918	**Plant Protection**

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ISBN:978-81-7164-235-9

VOL. 2

Azadi Ka Amrit Mahotsav

Agriculture and Allied Sciences

Restructured and Revised Syllabi of Post-graduate Programmes

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Education Division
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Printed : December 2021

ISBN: 978-81-7164-236-6

Published by Dr Satendra Kumar Singh, Project Director, Directorate of Knowledge Management in Agriculture, Indian Council of Agricultural Research, KAB-I, Pusa, New Delhi 110 012; laser typeset by Xpedite Computer Systems, WZ-276 F1-B, Inderpuri, New Delhi 110 012 and printed at M/s Chandu Press, 469, Patparganj Industrial Estate, Delhi 110 092.

सत्यमेव जयते

त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक

TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
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Foreword

THE ICAR has been continuously striving to bring necessary reforms for quality assurance in agricultural education. The Council has appointed National Core Group and BSMA Committees for revision and restructuring of Post-graduate and Doctoral syllabi in consultation with all the stakeholders to meet the challenges and harness opportunities in various disciplines of agriculture and allied sciences. It has been observed that a paradigm shift is necessary in academic regulations to comply with various provisions of National Education Policy-2020. It is heartening to note that the respective Committees have taken due care by following flexible, multi-disciplinary and holistic approach while developing the syllabus and academic regulations. The students are given opportunities to select the courses to support their planned research activities, to register for online courses and to pursue internship for development of entrepreneurship during Masters' programme. Further, the Teaching Assistantship has been introduced to provide experience to the Ph.D. scholars on teaching, evaluation and other related academic matters. This is an important part of doctoral training all over the world and it is expected to address the shortage of faculty in many institutions/universities. By intensive discussion with the subject experts and based on the feedback from the faculty and students, the syllabus of Masters' and Doctoral programmes in 79 disciplines was restructured and new courses were introduced. The syllabus has been revised suitably with the view to equip the students to gain knowledge, enhance their employability and skill sets to mould towards entrepreneurship and build themselves to prepare for global competitiveness. The opinions and suggestions invited from the concerned institutions, eminent scientists and other stakeholders were also reviewed by the Committees.

The Council sincerely thanks Dr Arvind Kumar, Chairman of the National Core Group and its members for the guidance to develop the syllabus in line with contemporary and projected national and global agricultural trends. The Council acknowledges the dedicated efforts and contribution of all the Chairpersons and members of 19 BSMA Committees for preparation of the syllabus. It gives me immense pleasure to express profuse thanks to the Agricultural Education Division for accomplishing this mammoth task under the guidance of Dr N.S. Rathore, former DDG and Dr R.C. Agrawal, DDG. I compliment Dr G. Venkateshwarlu, former ADG (EQR) for his sincere efforts and overall coordination of the meetings. Special thanks to DKMA for bringing out the entire syllabus in six volumes.

(T. Mohapatra)

Date: 13th August 2021
Place: New Delhi-110 001

Preface

THE curricula development is a part of the continued process and effort of the ICAR in this direction for dynamic improvement of national agricultural education system. In this resolve, the ICAR has constituted a National Core Group (NCG) for restructuring of Master's and Ph.D. curriculum, syllabi and academic regulations for the disciplines under agricultural sciences. On the recommendations of the NCG, 19 Broad Subject Matter Area (BSMA) Committees have been constituted by the ICAR for revising the syllabus. These Committees held discussions at length in the meetings and workshops organized across the country. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the Committees. The respective BSMA Committees have examined the existing syllabus and analysed carefully in terms of content, relevance and pattern and then synthesized the new syllabus.

The revised curricula of 79 disciplines has been designed with a view to improve the existing syllabus and to make it more contextual and pertinent to cater the needs of students in terms of global competitiveness and employability. To mitigate the concerns related to agriculture education system in India and to ensure uniform system of education, several changes have been incorporated in common academic regulations in relation to credit load requirement and its distribution, system of examination, internship during Masters programme, provision to enrol for online courses and take the advantage of e-resources through e-learning and teaching assistantship for Ph.D. scholars. As per recommendations of the National Education Policy-2020, the courses have been categorized as Major and Minor/Optional courses. By following the spirit of Choice Based Credit System (CBCS), the students are given opportunity to select courses from any discipline/department enabling the multi-disciplinary approach.

We place on record our profound gratitude to Dr Trilochan Mohapatra, Director General, ICAR, New Delhi, for providing an opportunity to revise the syllabi for PG and Ph.D. programs in agriculture and allied sciences. The Committee is deeply indebted to Dr R.C. Agrawal, DDG (Agri. Edn), and to his predecessor Dr N.S. Rathore for their vision and continuous support. Our thanks are due to all Hon'ble Vice Chancellors of CAUs/SAUs/DUs for their unstinted support and to nominate the senior faculty from their universities/institutes to the workshops organized as a part of wider consultation process.

The revised syllabi encompass transformative changes by updating, augmenting, and revising course curricula and common academic regulations to achieve necessary quality and need-based agricultural education. Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses have been incorporated based on their importance and need both at national and international level. We earnestly hope that this document will meet the needs and motivate different stakeholders.

G. Venkateshwarlu
Member-Secretary

Arvind Kumar
Chairman, National Core Group

Overview

A National Core Group has been constituted by ICAR for development of Academic Regulations for Masters and Ph.D. programmes, defining names and curricula of Masters' and Ph.D. disciplines for uniformity and revision of syllabi for courses of Masters' and Ph.D. degree disciplines. On the recommendations of the members of National Core Group, 19 Broad Subject Matter Area (BSMA) Committees have been constituted for revising the syllabus. These committees have conducted several meetings with the concerned experts and stakeholders and developed the syllabus for their respective subjects. While developing the syllabi, various provisions of National Education Policy-2020 have also been considered and complied to provide quality higher education and develop good, thoughtful, well-rounded, and creative individuals. Necessary provisions have been made in the curricula to enable an individual to study major and minor specialized areas of interest at a deep level, and also develop intellectual curiosity, scientific temper and creativity.

I express my gratefulness to Dr Arvind Kumar, Vice-Chancellor, Rani Lakshmi Bai Central Agricultural University, Jhansi and Chairman, National Core Group under whose guidance the syllabi for Master's and Doctoral programme is completed. His vast experience in agricultural education and research helped in finalising the syllabi. I wish to place on record the suggestions and directions shown by Dr N.S. Rathore, former Deputy Director General (Education) and Dr G. Venkateswarlu, ADG (EQR) and Member Secretary, National Core Group throughout the period without which the present target could not have been achieved. I am extremely thankful to 19 BSMA Committees for their stupendous job in restructuring and articulating curricula in the light of technological developments and employability prospects in agriculture and allied sciences. I also appreciate and acknowledge the efforts made by Dr S.K. Sankhyan, Principal Scientist (EQR), Dr S.K. Singh, Project Director (DKMA), Mr Punit Bhasin, Incharge, Production Unit (DKMA), Dr Kshitij Malhotra and Dr Sumit Saini, Research Associates to take up the work of editing, proof reading, finalizing and bringing out these six volumes of BSMA in this shape.

I also take this opportunity to express a deep sense of gratitude to Dr Trilochan Mohapatra, Secretary, DARE and Director General, ICAR for his guidance, cordial support and valuable input throughout the revision of the syllabus by BSMA, which helped in completing this task through various stages. The support and help extended by all Deputy Director Generals and the staff of Education Division is also greatly acknowledged.

During this comprehensive exercise of upgrading the course contents, the much-needed academic support, hospitality and participation rendered by Hon'ble Vice-Chancellors of CAUs/SAUs/DUs is greatly acknowledged. My deep sense of gratitude goes to Deans, Directors, Professors, Heads, faculty members and students at the universities who contributed by their effective participation and interaction.

R.C. Agrawal

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12. Definitions of academic terms

1. Academic Year and Registration

- An academic year shall be normally from July to June of the following calendar year otherwise required under special situations. It shall be divided into two academic terms known as semesters. Dates of registration, commencement of instructions, semester end examination, end of semester and academic year, etc. The Academic Calendar shall be developed by the concerned University from time to time and notified accordingly by the Registrar in advance.
- An orientation programme shall be organized by the Director (Education)/ Dean PGS for the benefit of the newly admitted students immediately after commencement of the semester.
- On successful completion of a semester, the continuing students shall register for subsequent semester on the date specified in the Academic/ Semester Calendar or specifically notified separately. Every enrolled student shall be required to register at the beginning of each semester till the completion of his/ her degree programmes.

2. Credit requirements

2.1 Framework of the courses

The following nomenclature and Credit Hrs need to be followed while providing the syllabus for all the disciplines:

		Masters' Programme	Doctoral Programme
(i)	**Course work**		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
	Seminar	01	02
(ii)	**Thesis Research**	30	75
	Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken may be given *mark

Minor courses: From the subjects closely related to a student's major subject

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/ her overallcompetence.

Common Courses: The following courses (one credit each) will be offered to all students undergoing Master's degree programme:

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the Head of Department (HoD)/ Board of Studies (BoS).

2.2 Supporting Courses

The following courses are being offered by various disciplines (The list is only indicative). Based on the requirement, any of the following courses may be opted under the supporting courses. The syllabi of these courses are available in the respective disciplines. If required, the contents may be modified to suit the individual discipline with approval of the concerned BoS:

Code	Course Title	Credit Hours
STAT 501	Mathematics for Applied Sciences	2+0
STAT 502	Statistical Methods for Applied Sciences	3+1

Course Code	Course Title	Credit Hours
STAT 511	Experimental Designs	2+1
STAT 512	Basic Sampling Techniques	2+1
STAT 521	Applied Regression Analysis	2+1
STAT 522	Data Analysis Using Statistical Packages	2+1
MCA 501	Computers Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Communication Technologies, Computer Networking and Internet	1+1
MCA 512	Information Technology in Agriculture	1+1
BIOCHEM 501	Basic Biochemistry	3+1
BIOCHEM 505	Techniques in Biochemistry	2+2

2.3 Syllabus of Common Courses for PG programmes

LIBRARY AND INFORMATION SERVICES (0+1)

Objective

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e-resources access methods.

TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

To equip the students/ scholars with skills to write dissertations, research papers, etc. To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical (Technical Writing)

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.;
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion);
- Writing of abstracts, summaries, précis, citations, etc.;

- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups;
- Editing and proof-reading;
- Writing of a review article;
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors), Concord, Collocation, Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech;
- Participation in group discussion;
- Facing an interview;
- Presentation of scientific papers.

Suggested Readings

1. Barnes and Noble. Robert C. (Ed.). 2005. *Spoken English: Flourish Your Language*.
2. *Chicago Manual of Style*. 14th Ed. 1996. Prentice Hall of India.
3. *Collins' Cobuild English Dictionary*. 1995.
4. Harper Collins. Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed.
5. Holt, Rinehart and Winston. Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed. Oxford University Press.
6. James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
7. Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
8. Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
9. Richard WS. 1969. *Technical Writing*.
10. Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
11. Wren PC and Martin H. 2006. *High School English Grammar and Composition*. S. Chand & Co.

INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE (1+0)

Objective

The main objective of this course is to equip students and stakeholders with knowledge of Intellectual Property Rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National

Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Readings

1. Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
2. Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
3. *Intellectual Property Rights: Key to New Wealth Generation*. 2001. NRDC and Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
5. Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
6. Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other Developing Countries: A Compendium on Law and Policies*. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; The Biological Diversity Act, 2002.

BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab;
- Handling of chemical substances;
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;
- Washing, drying and sterilization of glassware;
- Drying of solvents/ chemicals;
- Weighing and preparation of solutions of different strengths and their dilution;
- Handling techniques of solutions;
- Preparation of different agro-chemical doses in field and pot applications;
- Preparation of solutions of acids;
- Neutralisation of acid and bases;
- Preparation of buffers of different strengths and pH values;
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath;
- Electric wiring and earthing;
- Preparation of media and methods of sterilization;
- Seed viability testing, testing of pollen viability;
- Tissue culture of crop plants;
- Description of flowering plants in botanical terms in relation to taxonomy.

Suggested Readings

1. Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press.

2. Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (1+0)

Objective

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility.

UNIT II Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics.

UNIT III Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes.

Suggested Readings

1. Bhalla GS and Singh G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Publ.
2. Punia MS. *Manual on International Research and Research Ethics.* CCS Haryana Agricultural University, Hisar.
3. Rao BSV. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Publ.
4. Singh K. 1998. *Rural Development - Principles, Policies and Management*. Sage Publ.

2.4 Mandatory requirement of seminars

- It has been agreed to have mandatory seminars one in Masters (One Credit) and two in Doctoral programmes (two Credits).
- The students should be encouraged to make presentations on the latestdevelopments and literature in the area of research topic. This will provide training to the students on preparation for seminar, organizing the work, critical analysis of data and presentation skills.

3. Residential requirements

- The minimum and maximum duration of residential requirement for Masters'

Degree and Ph.D. Programmes shall be as follows:

P.G. Degree Programmes	Duration of Residential Requirement	
	Minimum	Maximum
Masters' Degree	2 Academic Years (4 Semesters)	5 Academic Years (10 Semesters)
Ph.D.*	3 Academic Years (6 Semesters)	7 Academic Years (14 Semesters)

*Student may be allowed to discontinue temporarily only after completion of course work

In case a student fails to complete the degree programme within the maximum duration of residential requirement, his/ her admission shall stand cancelled. The requirement shall be treated as satisfactory in the cases in which a student submits his/ her thesis any time during the 4^{th} and 6^{th} semester of his/ her residentship at the University for Masters' and Ph.D. programme, respectively.

4. Evaluation of course work and comprehensive examination

- For M.Sc., multiple levels of evaluation (First Test, Midterm and Final semester) is desirable. However, it has been felt that the comprehensive examination is redundant for M.Sc. students.
- For Ph.D., the approach should be research oriented rather than exam oriented. In order to provide the student adequate time to concentrate on the research work and complete the degree in stipulated time, the examination may have to be only semester final. However, the course teacher may be given freedom to evaluate in terms of assignment/ seminar/ first test.
- For Ph.D., the comprehensive examination (Pre-qualifying examination) is required. As the students are already tested in course examinations, the comprehensive examinationshould be based onoral examinationby an external expert and the evaluation should cover both the research problem and theoretical background to execute the project. This shall assess the aptitude of the student and suitability of the student for the given research topic. The successful completion of comprehensive examination is to obtain the "Satisfactory" remark by the external expert.

5. Advisory System

5.1 Advisory Committee

- There shall be an Advisory Committee for every student consisting of not fewer than three members in the case of a candidate for Masters' degree and four in the case of Ph.D. degree with the Advisor as Chairperson. The Advisory Committee should have representatives from the major and minor fields amongst the members of the Post-graduate faculty accredited for appropriate P.G. level research. However, in those departments where qualified staff exists but due to unavoidable reasons Post-graduate degree programmes are not existing, the staff having Post-graduate teaching experience of two years or more may be included in the Advisory Committee as member representing the minor.
- At any given time, a P.G. teacher shall not be a Chairperson, Advisory Committee (including Master's and Ph.D. programmes) for more than five students.

- The Advisor should convene a meeting of the Advisory Committee at least once in a Semester. The summary record should be communicated to the Head of Department, Dean of the College of concerned, Director (Education)/ Dean PGS and Registrar for information.

Advisor/ Co-guide/ Member, Advisory Committee from other collaborating University/ Institute/ Organization

- In order to promote quality Post-graduate research and training in cutting edge areas, the University may enter into Memorandum of Understanding (MOU) with other Universities/ Institutions for conducting research. While constituting an Advisory Committee of a student, if the Chairperson, Advisory Committee feels the requirement of involving of a faculty member/ scientist of such partnering university/ Institute/ Organization, he/ she may send a proposal to this effect to Director (Education)/ Dean PGS along with the proposal for consideration of Student's Advisory Committee (SAC).
- The proposed faculty member from the partnering institution can be allowed to act as Chairperson/ Co-guide/ Member, SAC, by mutual consent, primarily on the basis of intellectual input and time devoted for carrying out the research work at the particular institution. The faculty member/ scientist of partnering institutions in the SAC shall become a temporary faculty member of the University by following the procedure approved by the Academic Council.

Allotment of students to the retiring persons

Normally, retiring person may not be allotted M. Sc. Student if he/ she is left with less than 2 years of service and Ph.D. student if left with less than 3 years of service. However, in special circumstances, permission may be obtained from the Director (Education)/ Dean PGS, after due recommendation by the concerned Head of the Department.

Changes in the Advisory Committee:

(i) Change of the Chairperson or any member of the Advisory Committee is not ordinarily permissible. However, in exceptional cases, the change may be effected with due approval of the Director of Education/ Dean PGS.

(ii) Normally, staff members of the university on extra ordinary leave or on study leave or who leave the University service will cease to continue to serve as advisors of the Post-graduate students of the University. However, the Director (Education)/ Dean PGS may permit them to continue to serve as advisor subject to the following conditions:

   (a) The concerned staff member must be resident in India and if he/ she agrees to guide research and must be available for occasional consultations;

   (b) An application is made by the student concerned duly supported by the Advisory Committee;

   (c) In case of a Ph.D. student, he/ she must have completed his/ her comprehensive examinations and the research work must be well in progress and it is expected that the student will submit the thesis within a year;

   (d) The Head of the Department and the Dean of the College concerned agree to the proposal;

(e) The staff member, after leaving the University service is granted the status of honorary faculty's membership by the Vice-Chancellor on the recommendation of the Director (Education)/ Dean PGS for guiding as Chairperson or Member, Advisory Committee the thesis/ theses of the student(s) concerned only.

(iii) In case the Chairperson/ member of a Student's Advisory Committee retires, he/ she shall be allowed to continue provided that the student has completed his course work and minimum of 10 research credits and the retiring Chairperson/ member stays at the Headquarters of the College, till the thesis is submitted.

(iv) If the Chairperson/ member proceeds on deputation to another organization, he/ she may be permitted to guide the student provided his/ her new organization is at the Headquarters of the College and his/ her organization is willing for the same.

(v) The change shall be communicated to all concerned by the Head of Department.

6. Evaluation of research work

- It is highly desirablefor Ph.D. programme and this should be done annually as an essential part of research evaluation. The Student Advisory Committee shallreview the progress of research and scrutinize annual progress reports submitted by the student.
- Midterm evaluation of Ph.D. (to move from JRF to SRF) is a mandatory requirement for all the funding agencies. Hence, the second review of annual progress report need to be done after completion of two years. The successful completion enables the students to become eligible for SRF.

6.1 Prevention of plagiarism

- An institutional mechanism should be in place to check the plagiarism. The students must be made aware that manipulation of the data/ plagiarism is punishable with serious consequences.

7. Learning through online courses

- In line with the suggestion in new education policy and the initiatives taken by ICAR and MHRD in the form of e-courses, MOOCs, SWAYAM, etc. and also changes taking place globally in respect of learning through online resources it has been agreed to permit the students to enrol for online courses. It is expected that the provision of integrating available online courses with the traditional system of education would provide the students opportunities to improve their employability by imbibing the additional skills and competitive edge.

The Committee recommends the following points while integrating the online courses:

1. Board of Studies (BoS) of each Faculty shall identify available online courses and a student may select from the listed courses. The interested students may provide the details of the on-line courses to the BoS for its consideration.
2. A Postgraduate student may take up to a maximum of 20% credits in a semester through online learning resources.
3. The host institute offering the course does the evaluation and provide marks/ grades. The BoS shall develop the conversion formula for calculation of GPA and it may do appropriate checks on delivery methods and do additional evaluations, if needed.

8. Internship during Masters programme

Internship for Development of Entrepreneurship in Agriculture (IDEA)

Currently, a provision of 30 credits for dissertation work in M.Sc./ M.Tech/ M.F.Sc./ M.V.Sc. programmes helps practically only those students who aspire to pursue their career in academic/ research. There is hardly any opportunity/ provision under this system to enhance the entrepreneurship skills of those students who could start their own enterprise or have adequate skills to join the industry. Therefore, in order to overcome this gap, an optional internship/ in-plant training (called as IDEA) in lieu of thesis/ research work is recommended which will give the students an opportunity to have a real-time hands-on experience in the industry.

It is envisaged that the internship/ in-plant training would enhance the interactions between academic organizations and the relevant industry. It would not only enable the development of highly learned and skilled manpower to start their-own enterprises but also the industry would also be benefitted through this process. This pragmatic approach would definitely result in enhancedpartnerships between academia and industry.

The main objectives of the programme:

1. To promote the linkages between academia and industry
2. To establish newer University – Cooperative R&D together with industry for knowledge creation, research and commercialization
3. Collaboration between Universities and industries through pilot projects
4. To develop methods for knowledge transfer, innovation and networking potential
5. To enhance skill, career development and employability

Following criteria for IDEA will be taken into consideration:

- At any point of time there will not be more than 50% of students who can opt under IDEA
- Major Advisor will be from Academia and Co-advisor (or Advisory Committee member) from industry
- Total credits (30) will be divided into 20 for internship/ in-plant training and10 for writing the report followed by viva-voce similar to dissertation
- Work place will be industry; however, academic/ research support would be provided by the University or both. MoU may be developed accordingly
- The IPR, if any, would be as per the University policy

9. Teaching assistantship

- Teaching assistantship shall be encouraged. This will give the required experience to the students on how to conduct courses, practical classes, evaluation and other related academic matters. This is an important part of Ph.D. training all over the world and it is expected to address the shortage of faculty in many institutions/ universities.
- The fulltime doctoral students of the University with or without fellowship may be considered for award of Teaching Assistantships in their respective Departments. The Teaching Assistantship shall be offered only to those doctoral students who have successfully finished their course work. Any consideration for award of Teaching Assistantships must have the consent ofthe supervisor concerned.
- Teaching Assistantships shall be awarded on semester to semester basis on the recommendation of a screening/ selection committee to be constituted by the

ViceChancellor. All classes and assignments given to the Teaching Assistants, including tutorials, practicals and evaluation work shall be under the supervision of a faculty member who would have otherwise handled the course/ assignment.

- Each Ph.D. student may be allowed to take a maximum of 16 classes in a month to UG/ Masters students.
- No additional remuneration shall be paid to the students who are awarded ICAR JRF/ SRF. The amount of fellowship to be paid as remuneration to other students (who are receiving any other fellowship or without any fellowships) may be decided by the concerned universities as per the rules in force.However, the total amount of remuneration/ and fellowship shall not exceed the amount being paid as JRF/ SRF of ICAR.
- At the end of each term, Teaching Assistants shall be given a certificate by the concerned Head of the Department, countersigned by the School Dean, specifying the nature and load of assignments completed.

10. Registration of project personnel (SRF/ RA) for Ph.D.

- A provision may be made to enable the project personnel (SRF/ RA) to register for Ph.D. However, this can be done only if they are selected based on some selection process such as walk-in-interview. The prior approval of PI of the project is mandatory to consider the application of project personnel (SRF/ RA) for Ph.D. admission
- The candidates need to submit the declaration stating that the project work shall not be compromised because of Ph.D. programme. Further, in order to justify the project work and Ph.D. programme, the number of course credits should not be more than 8 in a semester for the project personnel (SRF/ RA) who intend to register for Ph.D.

11. Compliance with the National Education Policy-2020

- While implementing the course structure and contents recommended by the BSMA Committees, the Higher Education Institutions (HEIs) are required to comply with the provisions of National Education Policy-2020, especially the following aspects:
- Given the 21st century requirements, quality higher education must aim to develop good, thoughtful, well-rounded, and creative individuals. It must enable an individual to study one or more specialized areas of interest at a deep level, and also develop character, ethical and Constitutional values, intellectual curiosity, scientific temper, creativity, spirit of service, and 21st century capabilities across a range of disciplines including sciences, social sciences, arts, humanities, languages, as well as professional, technical, and vocational subjects. A quality higher education must enable personal accomplishment and enlightenment, constructive public engagement, and productive contribution to the society. It must prepare students for more meaningful and satisfying lives and work roles and enable economic independence (9.1.1. of NEP-2020).
- At the societal level, higher education must enable the development of an enlightened, socially conscious, knowledgeable, and skilled nation that can find and implement robust solutions to its own problems. Higher education must form the basis for knowledge creation and innovation thereby contributing to a growing national economy. The purpose of quality higher education is, therefore, more than the creation of greater opportunities for individual employment. It represents the key to more vibrant, socially engaged, cooperative communities and a happier,

cohesive, cultured, productive, innovative, progressive, and prosperous nation (9.1.3. of NEP-2020).

- Flexibility in curriculum and novel and engaging course options will be on offer to students, in addition to rigorous specialization in a subject or subjects. This will be encouraged by increased faculty and institutional autonomy in setting curricula. Pedagogy will have an increased emphasis on communication, discussion, debate, research, and opportunities for cross-disciplinary and interdisciplinary thinking (11.6 of NEP-2020).
- As part of a holistic education, students at all HEIs will be provided with opportunities for internships with local industry, businesses, artists, crafts persons, etc., as well as research internships with faculty and researchers at their own or other HEIs/ research institutions, so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability (11.8 of NEP-2020).
- HEIs will focus on research and innovation by setting up start-up incubation centres; technology development centres; centres in frontier areas of research; greater industry-academic linkages; and interdisciplinary research including humanities and social sciences research (11.12. of NEP-2020).
- Effective learning requires a comprehensive approach that involves appropriate curriculum, engaging pedagogy, continuous formative assessment, and adequate student support. The curriculum must be interesting and relevant, and updated regularly to align with the latest knowledge requirements and to meet specified learning outcomes. High-quality pedagogy is then necessary to successfully impart the curricular material to students; pedagogical practices determine the learning experiences that are provided to students, thus directly influencing learning outcomes. The assessment methods must be scientific, designed to continuously improve learning and test the application of knowledge. Last but not least, the development of capacities that promote student wellness such as fitness, good health, psycho-social well-being, and sound ethical grounding are also critical for high-quality learning (12.1. of NEP-2020).

Definitions of Academic Terms

Chairperson means a teacher of the major discipline proposed by the Head of Department through the Dean of the College and duly approved by the Director of Education/ Dean Post Graduate Studies (or as per the procedure laid down in the concerned University regulations) to act as the Chairperson of the Advisory Committee and also to guide the student on academic issues.

Course means a unit of instruction in a discipline carrying a specific number and credits to be covered in a semester as laid down in detail in the syllabus of a degree programme.

Credit means the unit of work load per week for a particular course in theory and/ or practical. One credit of theory means one class of one clock hour duration and one credit practical means one class of minimum two clock hoursof laboratory work per week.

Credit load of a student refers to the total number of credits of all the courses he/ she registers during a particular semester.

Grade Point (GP) of a course is a measure of performance. It is obtained by dividing the per cent mark secured by a student in a particular course by 10, expressed and rounded off to second decimal place.

Credit Point (CP) refers to the Grade point multiplied by the number of credits of the course, expressed and rounded off to second decimal place.

Grade Point Average (GPA) means the total credit point earned by a student divided by total number of credits of all the courses registered in a semester, expressed and rounded off to second decimal place.

Cumulative Grade Point Average (CGPA) means the total credit points earned by a student divided by the total number of credits registered by the student until the end of a semester (all completed semesters), expressed and rounded off to second decimal place.

Overall Grade Point Average (OGPA) means the total credit points earned by a student in the entire degree programme divided by the total number of credits required for the P.G. degree, expressed and rounded off to second decimal place.

Restructured and Revised
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Vol. 2

Physical Sciences

- Agricultural Meteorology
- Agronomy
- Soil Science
- Agricultural Physics
- Organic Farming

Contents

Acknowledgements

In order to obtain inputs from academia and representatives of related stakeholders, the committee met with various Vice Chancellors, Deans, Directors, Faculty members, Students of various State agricultural universities, Farmers and education/ teaching related stakeholders. To do so, the committee organized meetings in different regions of the country. It had its first meeting at Assam Agricultural University, Jorhat. The second meeting and the first workshop was held at Bihar Agricultural University, Sabour. The third meeting was held at Maharana Pratap University of Agriculture and Technology, Udaipur and the fourth meeting cum final workshop was held at Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The committee acknowledges the support and guidance provided by honorable Vice Chancellors of above Universities Dr K.M. Bujarbaruah, Dr A.K Singh, Dr Uma Shankar Sharma and Dr Praveen Rao Velchala, respectively and the co-ordinators for their contributions as well as facilitating the input gathering. The committee also places on record participation of enumerable faculty from various colleges and universities from across length and breadth of country who provided very useful inputs for preparing the curriculum.

Organic farming in its modern shape with science-based practices and the entire value chain moderated through standards for organic production and backed with robust certification system is fast catching up as an alternative commercial agricultural enterprise. Keeping in view of its growing importance and growing interest of farmers, trade and industry, a need was being felt by ICAR to initiate a postgraduate course in "Organic Farming". ICAR, therefore, constituted a committee for developing the course curriculum for M.Sc.Agriculture in Organic Farming and the committee after due deliberations has developed the syllabus and other requirements and is being presented along with Physical Science group as per the decision of the National Core Committee.

We express our sincere thanks to the committee members Dr A.K. Yadav, Chairman of the committee and Former Director, National Centre of Organic Farming and Currently Advisor (MOVCDNER), DAC&FW, New Delhi; Dr N. Ravishankar, Principal Coordinator NPOF Research, ICAR-IIFSR, Modipuram; Dr R.K. Awasthe, Jt. Director, ICAR-NOFRI, Sikkim; Dr J.P. Saini, Head, Centre of Excellence on Organic Farming, CSKHPKVV, Palampur, Himachal Pradesh; Dr N. Devakumar, Dean, UAS, Bangalore, Karnataka and Dr Mahesh Chander, Head EE, ICAR-IVRI, Izzatnagar, UP constituted for development of course syllabus of "Organic Farming".

The committee thanks Chairman, Dr Arvind Kumar, Vice Chancellor, Rani Lakshmi Bai Central Agricultural University, all the members National Core Group, chairpersons and conveners of other BSMA Committees for providing guidance and keeping the nomenclature as uniform.

Our sincere thanks are due to Dr Trilochan Mohapatra, Director General, Dr R.C. Agarwal DDG, Education, Dr N.S. Rathore, Former DDG, Education, Dr G. Venkateshwarlu, ADG, Education, Dr KL Khurana, Principal Scientist and the ICAR for providing us opportunity for contributing to a very nation building activities and rendering all the support for carrying out various meetings.

On a very personal note, we would like to place on record our sincere thanks and appreciations for all the members, namely, Dr Ajit Ram Sharma, Dr S.K. Thakral, Dr Vyas Pande, Dr Saon Banerjee, Dr Surendra Singh, Dr K.M. Manjaiah, and Dr (Ms) Pramila Krishnan for preparing the syllabus for related subjects and the report.

Dr Laxman Singh Rathore, Chairman
Dr Dipti Kumar Borah, Convener
BSMA Committee, Physical Science

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Agricultural Meteorology

Preamble

Agricultural Meteorology deals with the effects and impacts of weather and climate on agriculture and allied sectors. Climate, with its spatial and temporal variability, is a major influencing factor of crop production. Thus, any change in climatic elements is bound to have either positive or negative impacts on agricultural production. Along with this, climate change has led to increased intensity and frequency of extreme weather events such as heavy precipitation, cloud bursts, hail storm events, drought, etc. Here comes the importance of this discipline, which explores the principles of interaction of crops, livestock, fisheries, etc., with weather on a daily basis and with climate on a long-term basis. The relevance of the discipline is increasing over time, mainly due to the threats posed by climate variability and change in the present and future time. Considering the background and to promulgate the knowledge on role of weather for crop growth and development, new courses on Crop-weather relationship and Fundamentals of Agricultural Physics are included in the syllabus. Major changes are made in some courses considering the need of inclusion of recent advances and the new national initiatives. The repetition of content has been minutely scrutinized and modification has been done accordingly.

The provision of reliable weather information can be of great help for the decision making of farmers before and during the crop season for arranging the inputs and their optimum utilization. A well-timed agromet advisory can save inputs (fertilizers, seeds, plant protection chemicals, etc.), labour as well as the crop (especially at the harvest time after the crop reaches physiological maturity). Knowledge of Agricultural Meteorology helps in the efficient management of agro-climatic resources and crop microclimate modifications for the sustainability of agricultural production system. The students of this discipline should be sensitized towards the recent developments in information-communication technologies (ICT), which enables a faster, wider and timely dissemination of agromet advisories to the farmers of the country. Establishment of District-level Agromet Unit at different KVK is a great initiative by the Central Government and newly designed syllabus will empower the students to work in such types of project most efficiently.

The Agro-meteorologist requires not only a sound knowledge of Meteorology, but also of Agricultural Scince (Agronomy, Soil Science, Plant Sciences, and Animal Sciences), in addition to common agricultural practices. This branch ofscience is of particular relevance to India because of the high dependence of our agriculture on monsoon rainfall which has its own vagaries. A collective effort of agrometeorologist, agronomist, entomologist, pathologist and soil scientist make an information-rich agromet advisory, which will be of great help to the farmers. Another important area is the micrometeorology, which enables the farmers to modify the microclimate favourably to enhance the production.

Recent advances in space-borne (satellites), air-borne (UAVs) and ground remote sensing (spectro-radiometer) have improved the spatial and temporal capacity of the discipline for crop health monitoring, crop loss assessment, crop acreage estimation, etc. We are living in a world where tremendous advancement in computing power is enabling us to collect big data in agriculture, analyse it and arrive at conclusions, which helps to make farming a profitable business. The new syllabus will expose the students to the principles and practices of exploring remote sensing data, spatial analysis using Geographic information system (GIS), data analysis using computer programming with open source software like 'R' or/and 'Python'.The overall objective of this discipline is to educate students on the understanding of climate and weather elements, principles and processes, and their impact on agricultural activities and restructured course will help the students to achieve their goal.

Course Title with Credit Load
M.Sc. in Agriculture Meteorology

Course Code	Course Title	Credit Hours
AGM 501*	Fundamentals of Meteorology	2+1
AGM 502*	Fundamentals of Agricultural Meteorology	2+1
AGM 503	Crop-weather Relationships	2+0
AGM 504*	Agro-meteorological Measurements and Instrumentation	1+2
AGM 505	Crop Micrometeorology	2+1
AGM 506	Evapotranspiration and Soil Water Balance	2+1
AGM 507	Crop weather models	1+2
AGM 508	Applied Agricultural Climatology	1+2
AGM 509	Weather forecasting	2+1
AGM 510	RS and GIS Applications in Agricultural Meteorology	2+1
AGM 511	Strategic use of climatic information	2+1
AGM 512	Weather and climate risk management	2+0
AGM 513	Aerobiometeorology	2+1
AGM 591	Master's Seminar	1+0
AGM 599	Master's Research	30

*Indicates core courses for M.Sc.

Course Contents
M.Sc. in Agriculture Meteorology

I. Course Title : Fundamentals of Meteorology

II. Course Code : AGM 501

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge of physical processes occurring in atmosphere and techniques used in meteorology.

V. Theory

Unit I

Solar radiation and laws of radiation; greenhouse effect, albedo, and heat balance of the earth and atmosphere; variation in pressure and temperature with height, potential temperature, pressure gradient, cyclonic and anticyclonic motions; geostropic and gradient winds; equations of motion; general circulation, turbulence, vorticity, atmospheric waves.

Unit II

Gas laws, laws of thermodynamics and their application to atmosphere; water vapour in the atmosphere, various humidity parameters and their interrelationships; vapour pressure, psychrometric equation, saturation deficit, Lapse rates-ascent of dry and moist air, stability and instability conditions in the atmosphere.

Unit III

Agromet observatory and analysis of weather data; Condensation; clouds and their classification; evaporation and rainfall; the hydrological cycle; precipitation processes, artificial rainmaking, thunderstorms and dust storm; haze, mist, fog, and dew; air masses and fronts; tropical and extra-tropical cyclones.

Unit IV

Effect of Earth's rotation on zonal distribution of radiation, rainfall, temperature, and wind; the trade winds, equatorial trough and its movement;

Unit V

Monsoon and its origin; Indian monsoon and its seasonal aspects: Onset, advancement and retreat of monsoon in different parts of India, Walker and Hadley cell, El Nino, La Nina, Southern Oscillation Index and their impact on monsoon.

VI. Practical

- Agromet observatory- different classes of observatories (A, B, C)
- Site selection and installation procedures for meteorological instruments
- Measurement of weather parameters.
- Reading and recording, calculation of daily, weekly, monthly means.
- Totals of weather data.
- Weather chart preparation and identification of low pressure systems and ridges.
- Statistical technique for computation of climatic normals, moving average, etc.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

IX. Suggested Reading

- Ahrens. 2008. *Meteorology today*, 9th Edition. Wadsworth Publishing Co Inc.
- Barry RG and Richard JC. 2003. *Atmosphere, Weather and Climate*. Tailor & Fransics Group.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Ghadekar SR. 2001. *Meteorology*. Agromet Publishers (Nagpur).
- Ghadekar SR. 2002. *Practical Meteorology*. Agromet Publishers (Nagpur).
- Mcllveen R. 1992. *Fundamentals of Weather and Climate*. Chapman & Hall.
- Petterson S. 1958. *Introduction to Meteorology*. McGraw Hill.
- Trewartha Glenn T. 1954. *An Introduction to Climate*. McGraw Hill.
- Varshneya MC and Pillai PB. 2003. *Text Book of Agricultural Meteorology*. ICAR.

Journals

- *Mausam*
- *Journal of Agrometeorology*
- *Italian Journal of Agrometeorology*
- *Theoretical and Applied Climatology*

Websites

- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. Course Title : Fundamentals of Agricultural Meteorology

II. Course Code : AGM 502

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of physical processes occurring in relation to plant and atmosphere with advanced techniques.

V. Theory

Unit I

Meaning and scope of agricultural meteorology; components of agricultural meteorology; role and responsibilities of agricultural meteorologists.

Unit II

Importance of meteorological parameters in agriculture; efficiency of solar energy conversion into dry matter production; meteorological factors in photosynthesis, respiration and net assimilation; basic principles of water balance in ecosystems; soil-water balance models and water production functions.

Unit III

Crop weather calendars; weather forecasts for agriculture at short, medium and long range levels; agromet advisories, preparation, dissemination and economic impact analysis; use of satellite imageries in weather forecasting; synoptic charts and synoptic approach to weather forecasting.

Unit IV

Concept, definition, types of drought and their causes; prediction of drought; crop water stress index, crop stress detection; air pollution and its influence on vegetation, meteorological aspects of forest fires and their control.

Unit V

Climatic change, green house effect, CO_2 increase, global warming and their impact on agriculture; climate classification, agro-climatic zones and agro-ecological regions of India.

VI. Practical

- Preparation of crop weather calendars
- Development of simple regression models for weather, pest and disease relation in different crops.
- Preparation of weather based agro-advisories
- Use of automated weather station (AWS)

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Overall and basic knowledge on Agrometeorology

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Kakde JR. 1985. *Agricultural Climatology*. Metropolitan Book Co.
- Mahi and Kingra. 2014. *Fundamentals of agrometeorology*. Kalyani publishers.
- Mavi HS and Tupper. 2004. *Principles and applications of climate studies in agriculture*. CRC Press
- Varshneya MC and Pillai PB. 2003. *Text Book of Agricultural Meteorology*. ICAR.

Journals

- *Journal of Agrometeorology*
- *Italian Journal of Agrometeorology*
- *Agricultural and Forest Meteorology*
- *Current Science*

Websites

- http://www.imd.gov.in/pages/main.php
- http://www.fao.org/home/en/
- www.wmo.org
- www.ipcc.org

I. Course Title : Crop-weather Relationships

II. Course Code : AGM 503

III. Credit Hours : 2+0

IV. Aim of the course

To study and understand the role of weather on crop growth and development.

V. Theory

Unit I

Understanding the influence of weather elements on crop growth, impact of climatic variability and extremes on crop production, climatic normals for crop production.

Unit II

Climatic requirements of major crops, temperature effect on crop growth, radiation impact and radiation utlilization efficiency, humidity effect on crop performance, effect of soil temperature on seed germination and root growth, wind variation and crop growth.

Unit III

Meteorological indices to predict crop production, Interpretation of weather forecasts for various agricultural operations towards improved productivity, crop-weather relationship in dryland areas. Crop weather relationship of major horticultural crops of the region and agroforestry system.

Unit IV

Rhizosphere and microorganisms in relation to weather, fertilizer and water use efficiency in relation to weather.

VI. Teaching methods/activities

Classroom teaching

VII. Learning outcome

To enhance the knowledge on intricate relationship between crop and weather.

VIII. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Jerry L. Hatfield, Mannava VK, Sivakumar and John H. Prueger. 2017. *Agroclimatology: Linking Agriculture to climate*. Agronomy Monographs 60.
- Mavi HS. 1994. *Introduction to Agrometeorology*. Oxford & IBH.
- Prasada Rao GSLHV. 2008. *Agricultural Meteorology*. PHI Learning Publishers.

Journals

- *Journal of Agrometeorology*
- *Agricultural and Forest Meteorology*

Websites

- http://www.imd.gov.in/pages/main.php
- http://www.fao.org/home/en/

I. Course Title : Agro-meteorological Measurements and Instrumentation

II. Course Code : AGM 504

III. Credit Hours : 1+2

IV. Aim of the course

To impart the theoretical and practical knowledge of instruments/equipments used for measurement of agro-meteorological variables.

V. Theory

Unit I

Fundamentals of measurement techniques; theory and working principles of barometer, thermometer, psychrometer, hair hygrometer, thermohygrograph; exposure and operation of meteorological instruments/ equipments in agromet observatories.

Unit II

Radiation and temperature measuring instruments: working principles of albedometer, photometer, spectro-radiometer, sunshine recorder, dew recorder, quantum radiation sensors, pressure bomb apparatus, thermographs, and infra-red thermometer.

Unit III

Precipitation and dew instruments: working principles of rain gauge, self recording rain gauge, Duvdevani dew gauges. Wind instruments: working principles of anemometer, wind vane, anemograph.

Unit IV

Evapotranspiration and photosynthesis instruments: working principles of lysimeters, open pan evaporimeters, porometer, photosynthesis system, leaf area meter.

Unit V

Boundary layer fluxes, Flux tower, soil heat flux plates, instruments to measure soil moisture and soil temperature.

Unit VI

Automatic weather station – data logger and sensors, nano-sensors for measurement of weather variables; computation and interpretation of data.

VI. Practical

- Working with the above instruments in the meteorological observatory, fields and laboratory, Recording observations of relevant parameters.
- Computation and interpretation of the data.
- Analysis of AWS data.

VII. Teaching methods/activities

Mostly practical classes with demonstration and hands-on use of met-instruments

VIII. Learning outcome

Practical classes and theory

IX. Suggested Reading

- Anonymous. 1987. *Instructions to Observers at Surface Observatories*. Part I, IMD, New Delhi.
- Byers HR. 1959. *General Meteorology*. McGraw Hill.
- Ghadekar SR. 2002. *Practical Meteorology: Data Acquisition Techniques, Instruments and Methods*. Agromet Publ.
- Middleton WE and Spilhaws AF. 1962. *Meteorological Department*. University of Toronto Press.
- Tanner CB. 1973. *Basic Instrumentation and Measurements for Plant Environment and Micrometeology*. University of Wisconsin, Madison.
- WMO. 2008. *Guide to Meteorological Instruments and Methods of Observation*. WMO-No.8

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

https://public.wmo.int/en

I. Course Title : Crop Micrometeorology

II. Course Code : AGM 505

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of physical processes occurring in lower atmosphere and within crop canopy concerning crop growth.

V. Theory

Unit I

Properties of atmosphere near the Earth's surface; exchange of mass momentum and energy between surface and overlaying atmosphere, exchange coefficient, similarity hypothesis, shearing stress, forced and free convection.

Unit II

Molecular and eddy transport of heat, water vapour and momentum, frictional effects, eddy diffusion, mixing; zero plane displacement, temperature instability, eddy covariance technique, microclimate near the bare ground, unstable and inversion layers, variation in microclimate under irrigated and rainfed conditions, soil moisture and temperature variation with depth; Richardson number, Raymonds analogy, Exchange coefficients.

Unit III

Micrometeorology of plant canopies; distribution of temperature, humidity, vapour pressure, wind and carbon dioxide; modification of microclimate due to cultural practices, intercropping; radiation distribution and utilization by plant communities, leaf temperature and its biological effects; influence of topography on microclimate; shelter belts and wind breaks, microclimate in low plant area of meadows and grain fields, microclimate within forests, glass house and plastic house climates; instruments and measuring techniques in micrometeorology.

Unit IV

Effects of ambient weather conditions on growth, development and yield of crops; measurement of global and diffuse radiation; measurement of albedo over natural surfaces and cropped surfaces; net radiation measurement at different levels; PAR distribution in plant canopies and interception; wind, temperature and humidity profiles in (a) short crops and (b) tall crops; energy balance over crops and LAI and biomass estimation; remote sensing and its application in relation to micrometeorology.

VI. Practical

- Micrometerological measurements in crop canopies
- Quantification of crop microclimate
- Determination of ET and its computation by different methods.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

Knowledge of microclimatic conditions governing crop growth

IX. Suggested Reading

- Pal AS. 1988. *Introduction to Micrometeorology*. Academic Press.
- Bishnoi OP. 2007. Principles of Agricultural Meteorology. Oxford Book Co.
- Chang, Jen-Hu. 1968. *Climate and Agriculture: An Ecological Survey*. Aldine Publishing Company.
- Gates DM. 1968. *Energy Exchange in the Biosphere*. UNESCO.
- Goudriaan J. 1983. *Crop Micrometeorology: A Simulation Study*. Scientific Publ.
- Grace J. 1983. *Plant Atmospheric Relationships: Outline Studies in Ecology*. Chapman & Hall.
- Gupta PL and Rao VUM. 2000. *Practical Manual on Micrometeorology*. Dept. of Agril. Meteorology, CCS HAU Hisar, India.
- Jones HG. 1992. *Plants and Microclimate*. Cambridge Univ. Press. Munn RE. 1970. Biometeorological Methods. Academic Press.
- Monteith and Unsworth. 2013. *Principles of Environmental Physics*. Elsevier.
- Rosenberg NJ. 1974. *Microclimate – The biological Environmet*. John Wiley & Sons.
- Sellers W. 1967. *Physical Climatology*. The University of Chicago Press.

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

- https://public.wmo.int/en

I. Course Title : Evapotranspiration and Soil Water Balance

II. Course Code : AGM 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of ET estimation and determination of the components of soil water balance

V. Theory

Unit I

Energy concept of soil water, hydraulic conductivity and soil water flux; theory on hydraulic conductivity in saturated and unsaturated soils; physical factors concerning water movement in soil; concepts on evaporation, evapotranspiration, potential and actual evapotranspiration.

Unit II

Theories of evapotranspiration and their comparison; aerodynamic, eddy correlation, energy balance, water balance and other methods, their application under different agroclimatic conditions; concepts of potential, reference and actual evapotranspiration - modified techniques.

Unit III

Influence of microclimatic and cultural factors on soil water balance; techniques of lysimetry in measuring actual evapotranspiration. water use efficiency and scheduling of irrigation based on evapotranspiration; water use efficiency and antitranspirants, computation of Kc values and their use; irrigation scheduling based on climatological approaches.

Unit IV

Yield functions; water use efficiency and scheduling of irrigation based on evapotranspiration; dry matter yield ET functions; radiation instruments; advanced techniques for measurement of radiation and energy balance; estimation of evapotranspiration through remote sensing.

VI. Practical

- Measurement of various components of soil water balance
- Evaluation of hydraulic conductivity vs. soil moisture relationship by water balance approach
- Computation and comparison of evapotranspiration by different methods - energy balance method, aerodynamic method, Penman method, remote sensing and other methods
- Soil moisture retention characteristics by pressure plate method.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

To know the estimation procedures and interlinkages among different components of field water balance

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Burman R and Pochop LO. 1994. *Evaporation, Evapotranspiration and Climatic Data*. Elsevier.
- Grace J.1983. *Plant Atmospheric Relationships: Outline Studies in Ecology*. Chapman & Hall.
- Mavi HS and Tupper GJ. 2004. *Agrometeorology: Principles and Applications of Climate Studies in Agriculture*. The Haworth Press.
- Murthy VRK. 2002. *Basic Principles of Agricultural Meteorology*. BS Publ.
- Niwas R, Singh D and Rao VUM. 2000. *Pratical Manual on Evapotranspiration*. Dept. of Agril. Meteorology, CCS HAU Hisar.
- Rosenberg NJ, Blad BL and Verma SB. 1983. *Microclimate –The Biological Environment*. John Wiley & Sons.
- Subramaniam VP. 1982. *Water balance and its application*. Andhra University Press, Waltair, India.

Journals

- *Journal of Agrometeorology*
- *Archives of Agronomy and Soil Science*
- *Agricultural Water Management*
- *Journal of Hydrology*
- *Journal of Plant Ecology*

Websites

- https://www.icrisat.org/
- http://www.iwmi.cgiar.org/
- http://www.iiwm.res.in/

I. Course Title : Crop Weather Models

II. Course Code : AGM 507

III. Credit Hours : 1+2

IV. Aim of the course

To impart the theoretical and practical knowledge of various models for estimation of crop weather responses.

V. Theory

Unit I

Principles of crop production; effect of weather elements on crop responses; impact of natural and induced variability of climate on crop production.

Unit II

Introduction and application to crop modeling, types of models, Empirical and statistical crop weather models their application with examples; concept of crop growth model in relation to weather, soil, plant and other environmental related parameters and remote sensing inputs; growth and yield prediction models;

Unit III

Dynamic crop simulation models, e.g. DSSAT, InfoCrop, APSIM, CropSyst, etc.; optimization, calibration and validation of models. Weather data and physiology-based approaches to modeling of crop growth and yield; forecasting of pests and diseases; stochastic models; advantages and limitation of modeling.

VI. Practical

Working with statistical and simulation models, DSSAT models, InfoCrop, Oryza, etc.

VII. Teaching methods/activities

Theory and practical classes. Demonstration and hands-on practicals using crop models

VIII. Learning outcome

To utilize the crop weather model for observing weather influence on crop growth

IX. Suggested Reading

- Wallach D *et al*. *Working with dynamic crop models*.
- DeWit CT, Brouwer R and de Vries FWTP. 1970. *The Simulation of Photosynthetic Systems*. pp. 7-70. In. Prediction and Measurement of Photosynhetic Activity. Proc. Int. Biological Programme Plant Physiology Tech. Meeting Trebon PUDOC. Wageningen.
- Duncan WG. 1973. *SIMAI- A Model Simulating Growth and Yield in Corn*. In: The Application of Systems Methods to Crop Production (D.N. Baker, Ed.). Mississippi State Univ. Mississipi.
- Frere M and Popav G. 1979. *Agrometeorological Crop Monitoring and Forecasting*. FAO.
- Hanks RJ. 1974. *Model for Predicting Plant Yield as Influenced by Water Use*. Agron. J. 66: 660-665.
- Hay RKM and Porter JR. 2006. *The physiology of crop yield* (2nd Edition).
- Keulen H Van and Seligman NG. 1986. *Simulation of Water Use, Nitrogen Nutrition and Growth of a Spring Wheat Crop*. Simulation Monographs. PUDOC, Wageningen.
- Singh P. *Modelling of crop production systems: Principles and applications*.
- Weixing Cao *et al*. *Crop modeling and decision support*.

Journals

- *Journal of Agrometeorology*

- *Global Environmental Change*
- *Global Change Biology*
- *Mitigation and Adaptation Strategies for Global Change*

Websites

- https://www.apsim.info/
- https://dssat.net/

I. Course Title : Applied Agricultural Climatology

II. Course Code : AGM 508

III. Credit Hours : 1+2

IV. Aim of the course

To impart the theoretical and practical knowledge of computation of different bio-parameters and their applications in the agriculture.

V. Theory

Unit I

Climatic statistics: measures of central tendency and variability, skewness, kurtosis, homogeneity, correlation, regression and moving averages; probability analysis using normal, binomial, Markov-chain and incomplete gamma distribution; parametric and non parametric tests; assessment of frequency of disastrous events.

Unit II

Precipitation indices; Climatic water budget: potential and actual evapotranspiration and their computation; measurement of precipitation, calculation of water surplus and deficit; computation of daily and monthly water budget and their applications; assessment of dry and wet spells, available soil moisture, moisture adequacy index and their applications.

Unit III

Thermal indices and phenology: cardinal temperatures; heat unit and growing degree day concepts for crop phenology, crop growth and development; insect-pest development; crop weather calendars; agroclimatic requirement of crops.

Unit IV

Bioclimatic concepts: evaluation of human comfort, comfort indices (temperature, humidity index and wind chill) and clothing insulation; climate, housing and site orientation; climatic normals for animal production.

VI. Practical

- Use of statistical approaches in data analysis
- Preparation of climatic water budget
- Estimation of agro-meteorological variables using historical records
- Degree day concept and phenology forecasting and preparation of crop calendar
- Evaluation of radiation, wind and shading effects in site selection and orientation
- Study of weather-pest and disease interactions, calculation of continentality factors; calculation of comfort indices and preparation of climograph.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

Knowledge on how to use the meteorological observations and derived indices are applied in agricultural field

IX. Suggested Reading

- Anonymous 1980. *ICRISAT Climatic Classification – A Consultation Meeting*. ICRISAT.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Lal DS. 1989. *Climatology*. Chaitanya Publ. House.
- Mather JR. 1977. *Work Book in Applied Climatology*. Univ. of Delware, New Jersey.
- Mavi HS and Tupper Graeme J. 2004. *Agrometeorology: Principles and Applications of Climate Studies in Agriculture*. The Haworth Press.
- Stigter K (Ed.). 2010. *Applied Agrometeorology*. Springer
- Subramaniam VP. 1977. *Incidence and Spread of Continental Drought*. WMO/IMD Report No. 2, WMO, Geneva, Switzerland.
- Thompson R. 1997. *Applied Climatology: Principles and Practice*. Routledge.
- Walter J Saucier. 2003. *Principles of Meteorological Analysis*. Dover Phoenix Eds.

Journals

- *Theoretical and Applied Climatology*
- *Atmospheric Research Journal*
- *Journal of Agrometeorology*
- *Agricultural Climatology and Meteorology*
- *Journal of Applied Meteorology and Climatology*

Websites

- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. Course Title : Weather Forecasting

II. Course Code : AGM 509

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge of forecasting techniques used for weather prediction and preparation of agro-advisories.

V. Theory

Unit I

Weather forecasting system: definition, scope and importance; types of forecasting: short, medium and long-range; study of synoptic charts with special reference to location of highs and lows, jet streams, synoptic features and weather anomalies and zones of thermal advection and interpretation of satellite pictures of clouds in visible and infra-red range; weather forecasting network.

Unit II

Approaches for weather forecasts: methods of weather forecasts - synoptic, numerical prediction, statistical, analogue, persistence and climatological approach, nano-technological approach, Indigenous Technical Knowledge (ITK) base- signals from flora, fauna, insects, birds, animals behavior; various methods of verification of location-specific weather forecast.

Unit III

Special forecasts: special forecasts for natural calamities such as drought, floods, high winds, cold (frost) and heat waves, hail storms, cyclones and protection measures against such hazards.

Unit IV

Modification of weather hazards: weather modification for agriculture; scientific advances in artificial rain making, hail suppression, dissipation of fog and stratus clouds, modification of severe storms and electric behavior of clouds.

Unit V

Weather based advisories: interpretation of weather forecasts for soil moisture, farm operations, pest and disease development and epidemics, crops and livestock production; preparation of weather-based advisories and dissemination.

VI. Practical

- Exercise on weather forecasting for various applications
- Preparation of weather-based agro-advisories based on weather forecast using various approaches and synoptic charts.

VII. Teaching methods/ activities

Theory and practical classes

VIII. Learning outcome

Enhancing knowledge on weather forecast and its use

IX. Suggested Reading

- Watts A. 2005. *Instant Weather Forecasting*. Water Craft Books.
- Ram Sastry AA. 1984. *Weather and Weather Forecasting*. Publication Division, GOI, New Delhi.
- Singh SV, Rathore LS and Trivedi HKN. 1999. *A Guide for Agrometeorological Advisory Services*. Department of Science and Technology, NCMRWF, New Delhi.
- Wegman and Depriest. 1980. *Statistical Analysis of Weather Modification Experiments*. Amazon Book Co.

Journals

- *Journal of Climatology and Weather Forecasting*
- *Theoretical and Applied Climatology*
- *Atmospheric Research Journal*
- *Journal of Agrometeorology*
- *Agroclimatology*

Websites

- https://www.ipcc.ch/
- https://www.imd.gov.in/pages/main.php

I. Course Title : RS and GIS Applications in Agricultural Meteorology

II. Course Code : AGM 510

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of remote sensing principles and their use to estimate of agro-meteorological variables.

V. Theory

Unit I

Basic components of remote sensing- signals, sensors and sensing systems; active and passive remote sensing.

Unit II

Characteristics of electromagnetic radiation and its interaction with matter; spectral features of earth's surface features; remote sensors in visible, infrared and microwave regions.

Unit III

Imaging and non-imaging systems; framing and scanning systems; resolution of sensors; sensor platforms, their launching and maintenance. Drone technology.

Unit IV

Data acquisition system, data preprocessing, storage and dissemination; digital image processing and information extraction.

Unit V

Microwave remote sensing; visual and digital image interpretation; introduction to GIS and GPS.

Unit VI

Digital techniques for crop discrimination and identification; crop stress detection - soil moisture assessment, inventory of ground water and satellite measurement of surface soil moisture and temperature; drought monitoring, monitoring of crop disease and pest infestation. Use of satellite data in weather forecasting.

Unit VII

Soil resource inventory; land use/land cover mapping and planning; integrated watershed development; crop yield modeling and crop production forecasting.

VI. Practical

- Acquisition of maps
- Field data collection
- Map and imagery scales
- S/W and H/W requirements and specifications for remote sensing
- Data products, their specifications, media types, data inputs, transformation, display types, image enhancement
- Image classification methods
- Evaluation of classification errors
- Crop discrimination and acreage estimations
- Differentiation of different degraded soils
- Time domain reflectometry
- Use of spectrometer and computation of vegetation indices
- Demonstration of case studies
- Hands on training

VII. Teaching methods/activities

Hands on practicals and theory

VIII. Learning outcome

Knowledge on RS-GIS technique for application in Agricultural Meteorology

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Campbell JB. 1996. *Introduction to Remote Sensing*, 2nd ed., The Guilford Press, New York.
- Colwell RN. (Ed.). *Manual of Remote Sensing*. Vols. 1, II. Am. Soc. Photogrammetry, Virginia.
- Curan PJ. *Principles of Remote Sensing*. ELBS/Longman.
- Georg Joseph 2005.*Fundamentals of Remote Sensing*. University Press (India).
- Jain AK. 1989. *Fundamentals of Digital Image Processing*, Prentice Hall of India.
- Lilisand TM, Kiefer RW and Chipman JW. 2003. *Remote Sensing and Image Interpretation*, 5th ed., John Wiley & Sons, Inc., New York.
- Narayan LRA. 1999. *Remote Sensing and its Applications*. Oscar Publ.
- Panda BC. 2008. *Principles and Applications of Remote Sensing*, Viva Publications.
- Patel AN and Surender Singh. 2004. *Remote Sensing: Principles and Applications*. Scientific Publ.

Journals

- *Journal of Global Environmental Change*
- *Journal of Remote Sensing and GIS*
- *Journal of Agrometeorology*

Websites

- https://www.nrsc.gov.in/
- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. Course Title : Strategic Use of Climatic Information

II. Course Code : AGM 514

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of climatic hazards and their mitigations.

V. Theory

Unit I

Increasing awareness on potential climate hazards and mitigations: history of climate-related disasters in the concerned continent/ region/ country/ sub-region and their documented or remembered impacts; Climatic hazards and extreme weather events (Cyclone, Hailstorm, drought, flood, etc.), Impact of climatic hazard on agricultural production; efforts made in mitigating impacts of (future) disasters (prevention); trends discernible in occurrence and character of disasters, if any.

Unit II

Selection of appropriate land use and cropping patterns: types and drivers of agricultural land use and cropping patterns based on climatic situation; history of present land use and cropping patterns in the sub-region concerned as related to environmental issues; successes and difficulties experienced by farmers with present land use and cropping patterns; outlook for present land use and cropping patterns and possible alternatives from an environmental point of view.

Unit III

Adoption of preparedness strategies: priority settings for preparedness strategies in agricultural production; preparedness for meteorological disasters in development planning; permanent adaptation strategies that reduce the vulnerabilities to hazards; preparedness as a coping strategy.

Unit IV

Making more efficient use of agricultural inputs: agro-meteorological aspects of agricultural production inputs and their history; determination of input efficiencies based on weather conditions; other factors determining inputs and input efficiency; actual use of inputs in main land use and cropping patterns of the region.

Unit V

Adoption of microclimate modification techniques: review of microclimate management and manipulation methods; history of microclimate modification techniques practiced in the continent/ country/ sub-region concerned; possible improvements in adoption of microclimate modification techniques, given increasing climate variability and climate change; local trends in adoption of such techniques.

Unit VI

Protection measures against extreme climate: history of protection measures against extreme climate in the continent/ region/ country/ sub region concerned; successes and difficulties experienced by farmers with present protection measures; outlook for present protection measures and possible alternatives; trends in protection methods against extreme climate.

Practical

- Outlook for present land use and cropping patterns and possible alternatives from environmental point of view
- Recent trends in land use and cropping patterns
- Agro-meteorological services to increase farmers design abilities of land use and cropping patterns
- Systematic and standardized data collection on protection measures against extreme climate.

VI. Teaching methods/activities

Theory and practical classes

VII. Learning outcome

Application of climatic information for agriculture and natural resource management

VIII. Suggested Reading

- Anonymous. *Clean Development Mechanism: Building International Public-Private Partnership under Kyoto Protocol.* UNEP, UNDP Publ.
- Anonymous. *IPCC Assesment Reports on Climate Change Policy: Facts, Issues and Anlysis*. Cambridge Univ. Press.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Pretty J and Ball A. 2001. *Agricultural Influence on Carbon Emission and Sequestration: A Review of Evidence and the Emerging Trading Options*. Univ. of Essex.
- Pretty JN. 1995. *Regenerating Agriculture: Policies and Practices for Sustainable and Self Reliance*. Earthscan.

Journals

- *Climate Risk Management*, *Journal* of *Climate* (JCLI),
- *International Journal of Climatology*
- *Journal of Agrometeorology*

Website

https://www.ncdc.noaa.gov/climate-information

I. Course Title : Weather and Climate Risk Management

II. Course Code : AGM 515

III. Credit Hours : 2+0

IV. Aim of the course

To impart the theoretical and practical knowledge of weather modification techniques with risk management strategies

V. Theory

Unit I

Risk characterization – definitions and classification of risks; characterization of weather and climate related risks in agriculture; water related risks; radiation/ heat related risks; air and its movement related risks; biomass related risks; social and economic risk factors related to weather and climate.

Unit II

Risks in agricultural production, history of weather and climate as accepted risk factors in agriculture in the continent/ region/ country/ sub-region concerned and the related documented risk concepts; preparedness for weather and climate risks.

Unit III

Risks of droughts; monitoring, prediction and prevention of drought; drought proofing and management; modern tools including remote sensing and GIS in monitoring and combating droughts.

Unit IV

Theories of weather modification; scientific advances in clouds and electrical behavior of clouds; hails suppression, dissipation of fog, modification of frost intensity and severe storms; shelter belts and wind breaks, mulches and anti-transpirants; protection of plants against climatic hazards; air and water pollution; meteorological conditions in artificial and controlled climates - green, plastic, glass and animal houses, etc.

Unit V

Approaches and tools to deal with risks - history of methods for weather and climate related risk assessments in the continent/ region/ country/ subregion concerned and their documented evidence of application to agricultural/farming systems; strategies of dealing with risks- mitigating practices before occurrence; preparedness for the inevitable; contingency planning and responses; disaster risk mainstreaming.

Unit VI

Perspectives for farm applications - farm applications not yet dealt with, such as making risk information products more client friendly and transfer of risk information products to primary and secondary users of such information; heterogeneity of rural people in education, income, occupation and information demands and consequences for risk information products and their transfer; livelihood-focused support, participation and community perspectives; challenges for developing coping strategies including transferring risks through insurance schemes.

Unit VII

Challenges to coping strategies-combining challenges to disaster risk mainstreaming, mitigation practices, contingency planning and responses, basic preparedness; preparedness approaches reducing emergency relief necessities; the role that insurances can play in risk spreading and transfer; application of methods that permit the incorporation of seasonal and long-term forecasts into the risk assessment models.

VI. Teaching methods/ activities

Theory classes

VII. Learning outcome

Knowledge on different weather extremes and how to modify weather to reduce risk

VIII. Suggested Reading

- Anonymous 2003. *Critical Issues in Weather Modification Research Board of Atmoshperic Science and Climate*. National Research Council, USA.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Chritchfield HJ. 1994. *General Climatology*. Prentice Hall.
- Lenka D. 1998. Climate, Weather and Crops in India. Kalyani.
- Mavi HS and Graeme J Tupper. 2004. *Agrometeorology: Principles and Applications of Climate Studies in Agriculture*. The Haworth Press.
- Mavi HS. 1994. *Introduction to Agrometeorology*. Oxford & IBH.
- Menon PA. 1989. *Our Weather*. National Book Trust.
- Pearce RP. 2002. *Meteorology at the Millennium*. Academic Press.
- Rosenberg NJ, Blad BL and Verma SB. 1983. *Microclimate – The Biological Environment*. John Wiley & Sons.
- Samra JS, Narain P, Rattan RK and Singh SK. 2006. *Drought Management in India*. Bull. Indian Society of Soil Science 24, ISSS, New Delhi.

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

- https://www.icrisat.org/

I. Course Title : Aerobiometeorology

II. Course Code : AGM 516

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical knowledge on insect, pest and plant biometeorology

V. Theory

Unit I

Definition and structure of Aerobiometeorology, role of Agrometeorology and Biogeography in forecasting pests and disease outbreak, insect movement in the atmosphere, intensification, Effect of weather and climate parameters on reproduction, growth, development, movements, food, habitat and dispersal of pests and diseases. Influence of weather and climate on Migratory pests (Desert locust, BPH etc.).

Unit II

Benevolent and malevolent weather conditions for salient pests & diseases of the concerned agro-climatic zones. Effects of sudden weather changes and extreme weather conditions on population built-up of the pest, heat stress and heat related mortality, climate change impact on pest and diseases.

Unit III

Biometeorology in integrated pest and disease management program, modification of plant canopy and its impact of plant diseases, management of segments of disease triangle: environment manipulation and host manipulation, weather based forewarning system for pest and diseases.

Unit IV

Soil borne pathogens, their biology, management and challenges, soil borne diseases and their control, abiotic factor in soil borne disease management, Managing of pests & diseases in controlled environment, Environmental management for pest and disease

VI. Practical

- Identification of different pests
- Pest population, observations and their index calculation
- Identification of various diseases
- Disease initiation and their intensity, percent disease index
- Relation between weather parameters and pests and disease

VII. Teaching methods/activities

Classroom teaching and practical, visit to fields

VIII. Learning outcome

Knowledge on interactions between atmospheric processes and living organisms, mainly pest and diseases

IX. Suggested Reading

- Yazdani, SS and Agarwal ML. 2002. *Elements of insect ecology*. Narosa Publishing House.
- Odum EP. *Fundamentals of insect ecology*.
- Dhaliwal GS and Arora R. *Integrated pest management*.
- Jerry L. Hatfield and Ivan J. Thomason. 1982. *Biometeorology in integrated pest management*, Academic press.

Journals

- *Aerobiologica*
- *Journal of Agrometeorology*
- *International Journal* of *Biometeorology*

Website

- http://www.imd.gov.in

Course Title with Credit Load
Ph.D. in Agricultural Meteorology

Course Code	Course Title	Credit Hours
AGM 601*	Climate change and sustainable development	2+1
AGM 602	Meteorology of air pollution	2+2
AGM 603	Livestock and fisheries meteorology	2+2
AGM 604	Hydrometeorology	2+1
AGM 605	Analytical tools and methods for Agro-meteorology	1+1
AGM 606	Research and publication ethics	2+0
AGM 607	Environmental Physics for Agricultural Meteorology	3+0
AGM 608*	Computer Programs and Software for Agrometeorological data Management	1+1
AGM 691	Doctoral seminar	1+0
AGM 692	Doctoral seminar	1+0
AGM 699	Doctoral research	75

*Indicates core courses for PhD

Course Contents
Ph.D. in Agricultural Meteorology

I. Course Title : Climate Change and Sustainable Development
II. Course Code : AGM 601
III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of climate change and the cause, effect, mitigation of climate change.

V. Theory

Unit I

Climate change and global warming: definitions of terms; causes of climate change and global warming; greenhouse gases, ozone depletion; past records, present trends, extreme weather events and future projections; Case studies on various climatic projections and consequences thereof in relation to agriculture.

Unit II

Impacts of climate change on various systems: impacts resulting from projected changes on agriculture and food security; hydrology and water resources; terrestrial and freshwater ecosystems; coastal zones and marine ecosystems; human health; human settlements, energy, and industry; insurance and other financial services; climate change and crop diversification, loss of biodiversity, microbes and pest dynamics; climate change and storage, climate change and weed management. Advance methodology of assessing the impact of climate change on crops.

Unit III

Sensitivity, adaptation and vulnerability: system's sensitivity, adaptive capacity and vulnerability to climate change and extreme weather events; regional scenarios of climate change and variability.

Unit IV

Mitigation strategies for sustainable development: international policies, protocols, treaties for reduction in greenhouse gases and carbon emissions; carbon sequestration; carbon credit; Clean Development Mechanism (CDM) and land use, Crop management options for low emission, land use change and forestry mechanism, alternate energy sources, etc.

Unit V

Agricultural food security: reduction in carbon and GHG emission; fuel conservation and reduction in energy use, conservation tillage, biofuels for fossil fuels, reduction in machinery use etc; increasing carbon sinks; resource conservation technologies, mixed rotations of cover and green manure crops, minimization of summer fallow and no ground cover periods, etc.

VI. Practicals

- Case studies on various climatic projections and consequences thereof in relation to agriculture
- Advance methodology of assessing the impact of climate change on crops

VII. Teaching methods/ activities

Classroom teaching, showing climatic models (GCMs and RCMs) though PPT, Hands on practical

VIII. Learning outcome

Will be aware on causes, impacts, mitigation and adaptations to climate change in the field of agriculture

IX. Suggested Reading

- Anonymous. *Clean Development Mechanism: Building International Public-Private Partnership under Kyoto Protocol*. UNEP, UNDP Publ.
- Anonymous. *IPCC Assessment Reports on Climate Change* (2001, 2007). WMO, UNEP Publ.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Jepma CJ and Munasinghe M. 1998. *Climate Change Policy: Facts, Issues and Analysis.* Cambridge Univ. Press.
- Mintzer IM. 1992. *Confronting Climate Change: Risks, Implications and Responses*. Cambridge Univ. Press.
- Pretty J and Ball A. 2001. *Agricultural Influence on Carbon Emission and Sequestration: A Review of Evidence and the Emerging Trading Options*. Univ. of Essex.
- Pretty JN. 1995. *Regenerating Agriculture: Policies and Practices for Sustainable and Self Reliance*. Earthscan.
- Salinger J, Sivkumar MVK and Motha RP. 2005. *Increasing Climate Variability of Agriculture and Forestry*. Springer.
- Sinha SK. 1998. *Dictionary of Global Climate Change*. Commonwealth Publ.

Journal

- *Mitigation and Adaptation strategies for Global Change*
- *Climate Change*
- *Climate Risk Management*
- *Journal of Agrometeorology*

Website

- https://www.ipcc.ch/
- www.environment.gov.au/climate-change/climate-science-data/climate-science/ipcc

I. Course Title : Meteorology of Air Pollution

II. Course Code : AGM 602

III. Credit Hours : 2+2

IV. Aim of the course

To impart the theoretical and practical knowledge of air pollutants.

V. Theory

Unit I

Introduction to air pollution- history, definition: clean air definition; natural versus polluted atmosphere; atmosphere before the industrial revolution, Real time air quality index and National air quality index.

Unit II

Sources of air pollution; classification and properties of air pollutants; emission sources, importance of anthropogenic sources; behaviour and fate of air pollutants; photochemical smog; pollutants and trace gases. Acid rain and development of Gas Washing

Unit III

Meteorological factors in the dispersion of air pollutants; topographical, geographical and large scale meteorological factors attached air pollution; Planetary Boundary Layer (PBL) and mixing layer; meteorological conditions and typical plume forms; air pollution forecasting – Gaussian diffusion models, Numerical dispersion models.

Unit IV

Air quality standards; effect of air pollution on biological organisms; ozone layer depletion; air pollution control technologies; management of air pollution; principles of diffusion of particulate matter in the atmosphere; air pollution laws and standards. Scales of air pollution: local, urban, regional, continental and global.

Unit V

Air pollution sampling and measurement: types of pollutant sampling and measurement, ambient air sampling, collection of gaseous air pollutants, collection of particulate pollutants, stock sampling; analysis of air pollutants - sulfur dioxide, nitrogen dioxide, carbon monoxide, oxidants and ozone, hydrocarbons, particulate matter.

VI. Practicals

- Measurement of different air pollutants
- Measurement of different air pollution gases
- Measurement of visibility
- Measurement of ozone and aerosol optical thickness (AOT)
- To study the temperature profile at different heights
- To study the stability of the atmosphere
- To determine height of partial flume through chimani
- To study the effect of temperature on vegetables, orchards and agricultural crops

VII. Teaching methods/activities

Classroom teaching and practical

VIII. Learning outcome

Knowledge of sources and dispersal of pollutants, indexing, the influence of meteorological activities and analysis of pollutants

IX. Suggested Reading

- Arya SP. 1998. *Air Pollution Meteorology and Dispersion*. Oxford Univ. Press.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Chhatwa GR. 1989. *Environmental Air Pollution and its Control*. Anmol Publ.
- Mishra PC. 1990. *Fundamentals of Air and Water Pollution*. Ashish Publ.
- Mudd J Brian and Kozlowski TT. (Ed.). 1975. *Responses of Plants to Air Pollution*. Academic Press.
- Pickett EE. 1987. Atmopheric Pollution. Hemisphere Publ. Corp.
- Sharma SH and Khan TI. 2004. *Ozone Depletion and Environmental Impacts*. Pointer Publ.
- Weber E. 1982. *Air Pollution Assessment Methodology and Modeling*. Plenum Press.
- Yunus M and Iqbal M. (Eds.). 1996. *Plant Response to Air Pollution*. John Wiley & Sons.

Journals

- *Atmospheric Pollution* Research,
- *Environmental Pollution,*
- *Journal of Agrometeorology*

Website

- https://www.nationalgeographic.com/environment/global-warming/pollution/

I. Course Title : Livestock and Fisheries Meteorology

II. Course Code : AGM 603

III. Credit Hours : 2+2

IV. Aim of the course

To impart the theoretical and practical knowledge of weather, climate for livestock and fisheries management.

V. Theory

Unit I

Thermal balance in animals; energy exchange processes at the skin of the animals and the need for the maintenance of thermal balance in the animals. Animal traits and physiological responses.

Unit II

Effects of weather on animal production, loss of water from the body, growth rate and body weight, reproduction, grazing habit, food intake, milk production, sun burns and photosensitive disorders.

Unit III

Meteorological conditions prevailing in glass-house, green house, animal shed, poultry house and grain storage barns; heating, cooling and ventilation of these structures as governed by meteorological factors. Environmental modification within the shelters of livestock. Applications of biometeorological information for rational planning, design and management. Weather and animal diseases and parasites; diseases of poultry and its relation with weather and thermal comfort.

Unit IV

Livestock production and climate change, Management of livestock to reduce greenhouse gas emission.

Unit V

Weather effect on fish behaviour. Water temperature affecting fish activity. Marine weather and fishing. Climate change and fisheries production.

VI. Practical

- Measurement of meteorological parameters within the shelters of livestock
- Calculation of animal comfort zone index
- Radiation of animal farm house and body
- Estimation of enegy fluxes on body
- Measurements of CO_2 and methane in animal farm house.

VII. Teaching methods/activities

Class room teaching for theory part, visit to farm house for practical

VIII. Learning outcome

Enhanced knowledge on weather influence on livestock and farm environment

IX. Suggested Reading

- GSLHV Prasada Rao, GG Varma and Beena (Eds). 2017. *Livestock meteorology*. New India Publishing Agency- Nipa. 542 pages
- Kaiser HM and Drennen TE. (Eds). 1993. *Agricultural Dimensions of Global Climate Change*. St. Lucie Press, Florida.
- Monteith L and Unsworth M. 2007. *Principles of Environmental Physics*. 2nd Ed. Academic Press. Takahashi J, Young BA, Soliva CR and Kreuzer M. 2002. *Greenhouse Gases and Animal Agriculture*. Proc. 1st International Conference on Greenhouse Gases and Animal Agriculture.
- Tromp SW. 1980. *Biometeorology. The Impact of the Weather and Climate on Humans & their Environment*. (Animals and Plants). Heyden & Son Ltd.

Journals

- *Agricultural and Forest Meteorology,*
- *Journal* of *Animal Behaviour and Biometeorology,*
- *Journal of Agrometeorology*

Website

- www.wmo.org

I. Course Title : Hydrometeorology

II. Course Code : AGM 604

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of different components of hydrologic cycle.

V. Theory

Unit I

Hydrologic cycle and its modification; rainfall and its interception by plants and crops. Interpolation and measurement of missing rainfall data; adequacy of rain gauges; average rainfall on an area depth basis; presentation and processing of precipitation data.

Unit II

Measurement of runoff, infiltration, moisture retention of soil, percolation, evaporation, evapotranspiration and its importance to agriculturists, irrigation engineers and flood forecasting personnel; water holding capacity of soils, plant available water, cultural practices on soil moisture in relation to different phases of crop growth; evaporation from snow, lakes, reservoirs and crop fields.

Unit III

Classifying rainfall data into class interval; ranking of rainfall data; relationship between intensity and duration; methods of predicting runoff rate; factors affecting runoff; rainfall-runoff relation; estimation of evapotranspiration from water balance methods; response of crops to water stresses under different agroclimatic situation on India.

Unit IV

Moisture availability indices and their application for Indian condition; wet and dry spell by Markov-chain model; drought and its classification, hydrological drought, drought indices and their applications under Indian conditions.

VI. Practical

- Analysis of rainfall data
- Determination of effective rainfall
- To estimate missing rainfall data for a given station.
- To find out the optimum number of rain gauges for a given catchment.
- To find out the mean rainfall for a given drainage basin by Thiessen polygon method and isohyetal method.
- To estimate the volume of runoff by SCS method.
- Estimation of evopotranspiration from field based water balance method.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

Knowledge on rainfall analysis, runoff estimation, calculation of evaporation and the relationship among different hydrological parameters

IX. Suggested Reading

- Chow, Ven Te (Ed.). 1964. *Handbook of Applied Hydrology*. McGraw-Hill.
- Hillel D. 1971. *Soil and Water*. Academic Press.
- Hillel D. 1980. *Application of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physics*. Academic Press.

Journal

- *Journal* of *Hydrology, Journal* of *Hydrology and Meteorology,*
- *Agricultural Water Management,*
- *Journal of Agrometeorology*

Website

- https://has.arizona.edu/meteorology-hydrology-and-hydrometeorology
- www.abb.com/cawp/seitp161/4f39ac092c0598c9c1256fb8004f7726.aspx

I. Course Title : Analytical Tools and Methods for Agro-meteorology

II. Course Code : AGM 605

III. Credit Hours : 1+1

IV. Aim of the course

To impart the theoretical and practical knowledge of new tools for analysis of agro-climatic features.

V. Theory

Unit I

Review of agro-climatic methods; characterization of agroclimatic elements; sampling of atmosphere; temporal and spatial considerations; micro-meso-macro climates.

Unit II

Network spacing; spatial and temporal methods; GIS fundamentals and applications; numerical characterization of climatic features; crop response to climate, time lags, time and distance constants, hysteresis effects.

Unit III

Influence of climate on stress-response relations; thermal time approach in agroclimatology- heat and radiation use efficiency in crop plants; applications to insect-pest development and prediction; comfort indices for human and animals; impact of natural and induced variability and change of climate on crop production.

Unit IV

Instrumentation and sampling problems; design of agro-meteorological experiments.

Unit V

Basic knowledge of application of computers in agriculture; theories of computer language BASIC, FORTRAN, C, C++ and Visual basic.

Unit VI

Empirical and statistical crop weather models and their application with examples; incorporating weather, soil, plants and other environment related parameters as subroutine and remote sensing inputs in models; growth and yield prediction models; crop simulation models; forecasting models for insects and diseases.

VI. Practical

- Calculation of continentality factors.
- Climatic indices and climogram.
- Agrometeorological indices: Degree-days, photothermal units, heliothermal units, phenothermal index.
- Heat and radiation use efficiency and other indices of crops.
- Crop growth rates.
- Analysis of thermogram, hygrogram, hyetogram, sunshine cards etc. stream lines and wind roses and statistical analysis of climatic data.
- Working with statistical models: crop yield forecasting, crop weather relationship and insect & disease forecasting models.
- Working with crop simulation models
- Small programme writing in computer languages like BASIC, FORTRAN, C, C++ and Visual basic.
- Geographical Information System.

VII. Teaching methods/activities

Theory and practical classes, learning of computer language

VIII. Learning outcome

Knowledge on collection of agromet data, sampling design for agrometeorology, calculation of different indices and analysis of data

IX. Suggested Reading

- Cooper M. 2006. *The Spirit of C. An Introduction to Modern Programming*. Jaico Publ.
- Malczewski J. 1999. *GIS & Multicriteria Decision Analysis*. John Wiley & Sons.
- WMO. 2010. *Guide to agricultural meteorological practices*. Chapter 3: agricultural meteorological data, their presentation and statistical analysis

Journals

- *The International Journal* of *Database Management* Systems
- Journal of Agrometeorology

Website

- https://www.tropmet.res.in/~icrp/icrpv12/adach.html
- www.wmo.int/pages/prog/wcp/agm/gamp/documents/WMO_No134_en.pdf

I. Course Title : Research and Publication Ethics

II. Course Code : AGM 606

III. Credit Hours : 2+0

IV. Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit IV

Publication ethics: Defination, introduction and importance. Best practices/ standard setting initiatives and guidelines: COPE, WAME etc., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatory publishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to check publisher copy right and self archiving policies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools, viz., JANE, Elsevier Journal Finder, Springer Journal Suggester etc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open source software tools.

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, etc. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, Gindex, i 10 index altmetrics

V. Teaching methods/activities

Classroom teaching and field and laboratory activities

VI. Learning outcome

To familiarize the students about field and laboratory activities to be performed during the study period

I. Course Title : Weather and Climate Risk Management
II. Course Code : AGM 607
III. Credit Hours : 3+0

IV. Aim of the course

To impart the theoretical knowledge of Physics applied to atmosphere and meteorology

V. Theory

Unit I

Thermodynamics of the atmosphere. Physics of radiation: origin and nature of radiation, radiation geometry in Cartesian, spherical cylindrical coordinate systems, conservation principles for radiant energy; fluid motion: laminar and turbulent transfer, fluctuation theory for turbulent transfer of momentum, heat and water vapour.

Unit II

Physics of evaporation: aerodynamic approach, energy balance approach and combination approach for evaporation estimates.

Unit III

Physics of soil water system: the concept of potential as applied to soil water system, total potential and components, movements of water on soil, fundamental equation, hydraulic conductivity, infiltration, field drainage and water vapour movement in soil.

Unit IV

Physics of water use: a physical introduction to plant-water system and relationships, water transport through soil-plant-atmosphere systems, measurement of crop water use in terms of water conservation equation.

VI. Teaching methods/activities

Classroom teaching

VII. Learning outcome

Knowledge and application of physical laws governing the agrometeorological parameters

VIII. Suggested Reading

- Hillel D. 1971. *Soil and Water*. Academic Press.
- Hillel D. 1980. *Application of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physics*. Academic Press.
- Monteith JL .1973. *Principles of Environmental Physics*. Edward Arnold.
- Rose CW. 1966. *Agricultural Physics*. Pergamon Press.
- Sellers WD. 1965. *Physical Climatology*. University of Chicago Press.
- Van Wizk WR. 1963. *Physics of Plant Environment*. North-Holland Publishing.
- Waggoner PE. (Ed.). 1965. *Agricultural Meteorology*. American Meteorological Society.

Journals

- *Journal of Meteorological Research,*
- *Agricultural and Forest Meteorology*

Website

- https://fmph.uniba.sk/.../enviromentalna-fyzika-obnovitelne-zdroje-energie-meteorolo...

I. Course Title : Computer Programs and Software for Agrometeorological Data Management

II. Course Code : AGM 608

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge on management of agromet data and train the students in commercialization of agrometeorological data through e-services.

V. Theory

Unit I

Data and information; types of data; climate, soil and crop data; Importance of database management, Softwares related to database management; data requirements; data collection and recording (Automatic and manual).

Unit II

Data structure/format; quality control of data through computer software; techniques of climatic data generation; missing data; introduction to different software for database management.

Unit III

Processing and analysis of data and data products; value addition of data and data products; data users, public, commercial, academic or research. Availability, accessibility and security of data; evaluating the cost of data; e-management of data. Meta analysis: Advantages and problems, Steps, Approaches and methods, Applications.

Unit IV

Computer Programming: History, Quality requirements, Readability of source code, Algorithmic complexity, Debugging, Programming languages

VI. Practical

- Types of instruments and data recording
- AWS data retrieval, storage and transfer
- Exposure to different software for Agromet data analysis; exposure to Statistical software
- Temporal and spatial analysis of data; exposure to GIS
- Value addition to data
- Introduction to internet protocols
- Uploading and downloading data, password and security of data
- E-management of data
- Introduction to computer programming

VII. Teaching methods/activities

Hands on practical and theory

VIII. Learning outcome

Learning computer programming to manage and analyze agromet data

IX. Suggested Reading

- Ghadekar R. 2002. *Practical Meteorology – Data Acquisition Techniques, Instruments and Methods*. 4th Ed. Agromet Publ.
- IMD/ WHO. 1988. *Users Requirements for Agrometeorological Services*. IMD.
- Miles MB and Huberman AM. 1994. *Qualitative Data Analysis*. Sage Publ.
- Panse VG and Sukhatme PV. 1983. *Statistical Methods for Agricultural Workers*, ICAR.
- Potter GB. 1994. *Data Processing: An Introduction*. Business Publ.
- Ramakrishnan R and Gehrke J. 2003. *Database Management System*. McGraw-Hill.
- Sinha PK and Sinha P. 2004. *Computer Fundamentals*. BPB Publications. (6^{th} Edn).

Journals

- *The Journal* of *Database Management*
- *International Journal* of Data Mining
- *Modelling and Management*

Websites

- https://www.cics.umass.edu/research/area/data-management
- https://www.referenceforbusiness.com/management/.../Data-Processing-and-Data-Man.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Agronomy

Preamble

Agronomy is a discipline which deals with various processes such as cultivation, interculture, management of field through various measures like weed management, soil fertility development, proper use of water resources and so on. Agronomy has a major component of agro ecology which includes several activities that affect the environment and human population. An Agronomist remains in the centre of effort to work with issues related to environmental and ecological concerns and to increase the production of food, feed, fuels and fibre for growing population in world. Agronomist today are involved with many issues including producing food, creating healthier food, managing environmental impacts and creating energy from plants. Research activities in Agronomy focus on system analysis and simulation modeling of environmental and management impacts on agricultural production, these are key to the sustainability of agricultural production system.

Hence, it is very much essential to revise the course curriculum of Agronomy so that students even teachers may be well acquainted with the present concept of development of the discipline. This will help bringing competency in students along with confidence so as to develop himself/ herself for being tackling field problems and management of land.The existing M.Sc. (Ag) courses of Agronomy have been modified taking into account of present day need by incorporating the necessary and important topics in the respective courses.

Minor changes have been made in most of the existing courses. As a part of course curriculum, M. Sc.(Ag) Agronomy was restructured to equip students to tackle emerging issues by inclusion of one new course on “Conservation agriculture”. All the Ph.D courses of Agronomy was slightly revised by adding/ deleting some some portion in the existing courses. The course “Fundamentals of Meteorology” is dropped from Agronomy department and interested students can take the course from department of Agril.Meteorology. The course “Agroecology” offered by the department for Ph D programme is also dropped. Similarly, the Ph.D. course “Crop production and system modeling” is also deleted and the contents are merged with Agron 601, i.e. “Current trends in Agronomy”.

It was proposed by some members to include new courses like “Seed production technology”, “Experimental technique in Agronomy” and “Management of Problem soils and water”. But finally, it was decided that these courses should be offered by the core departments such as Department of Seed Technology, Department of Statistics and Department of Soil Science, respectively. There are few courses in the existing syllabus which are not offered by in many universities. Hence these courses are merged and thereby reduced the number of courses to limit choice so that complete knowledge of the subject can be given to the students. In all the courses, the practical aspects are strengthened.

Topics such as automated irrigation systems, value chain addition/ post harvest processing, variable rate application, precision farming, protected agriculture, soil less farming, farm mechanization of practical operations, practical applications of advanced tools for big data analysis and interpretation, artificial intelligence, drones etc are included in the revised syllabus so that students can show competency at national and international level.

Course Title with Credit Load
M.Sc. in Agronomy

Course Code	Course Title	Credit Hours
Agron 501*	Modern Concepts in Crop Production	3+0
Agron 502*	Principles and practices of soil fertility and nutrient management	2+1
Agron 503*	Principles and Practices of Weed Management	2+1
Agron 504*	Principles and Practices of Water Management	2+1
Agron 505	Conservation Agriculture	1+1
Agron 506	Agronomy of major Cereals and Pulses	2+0
Agron507	Agronomy of oilseed, fibre and sugar crops	2+1
Agron 508	Agronomy of medicinal, aromatic & underutilized crops	2+1
Agron 509	Agronomy of fodder and forage crops	2+1
Agron 510	Agrostology and Agro- Forestry	2+1
Agron 511	Cropping System and Sustainable Agriculture	2+0
Agron 512	Dryland Farming and Watershed Management	2+1
Agron 513	Principles and practices of organic farming	2+1
Agron-550	Master's Seminar	(1+0)
Agron -560	Master's research	-30

*Indicates core course which is Compulsory course for M Sc.(Agri)

Course Contents
M.Sc. in Agronomy

I. Course Title : Modern Concepts in Crop Production
II. Course Code : Agron 501
III. Credit Hours : 3+0

IV. Aim of the course

To teach the basic concepts of soil management and crop production.

V. Theory

Unit I

Crop growth analysis in relation to environment; geo-ecological zones of India.

Unit II

Quantitative agro-biological principles and inverse yield nitrogen law; Mitscherlich yield equation, its interpretation and applicability; Baule unit.

Unit III

Effect of lodging in cereals; physiology of grain yield in cereals; optimization of plant population and planting geometry in relation to different resources, concept of ideal plant type and crop modeling for desired crop yield.

Unit IV

Scientific principles of crop production; crop response production functions; concept of soil plant relations; yield and environmental stress, use of growth hormones and regulators for better adaptation in stressed condition.

Unit V

Integrated farming systems, organic farming, and resource conservation technology including modern concept of tillage; dry farming; determining the nutrient needs for yield potentiality of crop plants, concept of balance nutrition and integrated nutrient management; precision agriculture.Modern crop production concepts: soil less cultivation, Aeroponic, Hydroponic, Robotic and terrace farming. use of GIS, GPS and remote sensing in modern agriculture, precision farming and protected agriculture.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VII. Learning outcome

Basic knowledge on soil management and crop production

VIII. Suggested Reading

- Balasubramaniyan P and Palaniappan SP. 2001. *Principles and Practices of Agronomy*. Agrobios.
- Fageria NK. 1992. *Maximizing Crop Yields*. Marcel Dekker.
- Havlin JL, Beaton JD, Tisdale SL and Nelson WL. 2006. *Soil Fertility and Fertilizers*. 7th

Ed. Prentice Hall.
- Paroda R.S. 2003. *Sustaining our Food Security*. Konark Publ.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani Publ.
- Sankaran S and Mudaliar TVS. 1997. *Principles of Agronomy*. The Bangalore Printing & Publ.
- Singh SS. 2006. *Principles and Practices of Agronomy*. Kalyani.
- Alvin PT and kozlowski TT (ed.). 1976. *Ecophysiology of Tropical Crops*. Academia Pul., New York.
- Gardner PP, Pearce GR and Mitchell RL. 1985. *Physiology of Crop Plants*. Scientific Pub. Jodhpur.
- Lal R. 1989. *Conservation tillage for sustainable agriculture: Tropics versus Temperate Environments. Advances in Agronomy* 42: 85-197.
- Wilsie CP. 1961. *Crop Adaptation and Distribution*. Euresia Pub., New Delhi.

I. Course Title : Principal and Practices of Soil Fertility and Nutrient Management

II. Course Code : Agron 502

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge of fertilizers and manures as sources of plant nutrients and apprise about the integrated approach of plant nutrition and sustainability of soil fertility.

V. Theory

Unit I

Soil fertility and productivity - factors affecting; features of good soil management; problems of supply and availability of nutrients; relation between nutrient supply and crop growth; organic farming - basic concepts and definitions.

Unit II

Criteria of essentiality of nutrients; Essential plant nutrients – their functions, nutrient deficiency symptoms; transformation and dynamics of major plant nutrients.

Unit III

Preparation and use of farmyard manure, compost, green manures, vermicompost, biofertilizers and other organic concentrates their composition, availability and crop responses; recycling of organic wastes and residue management. Soil less cultivation.

Unit IV

Commercial fertilizers; composition, relative fertilizer value and cost; crop response to different nutrients, residual effects and fertilizer use efficiency; agronomic, chemical and physiological, fertilizer mixtures and grades; methods of increasing fertilizer use efficiency; nutrient interactions.

Unit V

Time and methods of manures and fertilizers application; foliar application and its concept; relative performance of organic and inorganic nutrients; economics of fertilizer use; integrated nutrient management; use of vermincompost and residue wastes in crops.

VI. Practical

- Determination of soil pH and soil EC
- Determination of soil organic C
- Determination of available N, P, K and S of soil
- Determination of total N, P, K and S of soil
- Determination of total N, P, K, S in plant
- Computation of optimum and economic yield

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on soil fertility and management

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils.* 13th Ed. Pearson Edu.
- Fageria NK, Baligar VC and Jones CA. 1991. *Growth and Mineral Nutrition of Field Crops.* Marcel Dekker.
- Havlin JL, Beaton JD, Tisdale SL and Nelson WL. 2006. *Soil Fertility and Fertilizers.* 7th Ed. Prentice Hall.
- Prasad R and Power JF. 1997. *Soil Fertility Management for Sustainable Agriculture.* CRC Press.
- Yawalkar KS, Agrawal JP and Bokde S. 2000. *Manures and Fertilizers.* Agri-Horti Publ.

I. Course Title : Principles and Practices of Weed Management

II. Course Code : Agron 503

III. Credit Hours : 2+1

IV. Aim of the course

To familiarize the students about the weeds, herbicides and methods of weed control.

V. Theory

Weed biology, and ecology and classification, crop-weed competition including allelopathy; principles and methods of weed control and classification management; weed indices, weed shift in different eco-systems

Unit II

Herbicides introduction and history of their development; classification based on chemical, physiological application and selectivity; mode and mechanism of action of herbicides.

Unit III

Herbicide structure - activity relationship; factors affecting the efficiency of herbicides; herbicide formulations, herbicide mixtures, sequential application of herbicides, rotation; weed control through use ofnano-herbicides and bio-herbicides, myco-herbicides bio-agents, and allelochemicals; movement of herbicides in soil and plant, Degradation of herbicides in soil and plants; herbicide resistance, residue, persistence and management; development of herbicide resistance in weeds and crops and their management, herbicide combinationand rotation.

Unit IV

Weed management in major crops and cropping systems; alien, invasive and parasitic weeds and their management; weed shifts in cropping systems; aquatic and perennial weed control; weed control in non-crop area.

Unit V

Integrated weed management; recent development in weed management- robotics, use of drones and aeroplanes, organic etc., cost: benefit analysis of weed management.

VI. Practical

- Identification of important weeds of different crops, Preparation of a weed herbarium, Weed survey in crops and cropping systems, Crop-weed competition studies, Weed indices calculation and interpretation with data, Preparation of spray solutions of herbicides for high and low-volume sprayers, Use of various types of spray pumps and nozzles and calculation of swath width, Economics of weed control, Herbicide resistance analysis in plant and soil,
- Bioassay of herbicide resistance residues,
- Calculation of herbicidal herbicide requirement

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field visit to identify weeds.

VIII. Learning outcome

Basic knowledge on weed identification and control for crop production

IX. Suggested Reading

- Böger, Peter, Wakabayashi, Ko, Hirai, Kenji (Eds.). 2002. *Herbicide Classes in Development. Mode of Action*, *Targets*, *Genetic Engineering*, *Chemistry*. Springer.
- Chauhan B and Mahajan G. 2014. *Recent Advances in Weed Management*. Springer.
- Das TK. 2008. *Weed Science: Basics and Applications*, Jain Brothers (New Delhi).
- Fennimore, Steven A and Bell, Carl. 2014. *Principles of Weed Control*, 4th Ed, California Weed Sci. Soc.
- Gupta OP. 2007. *Weed Management*: *Principles and Practices*, 2nd Ed.
- Jugulan, Mithila (ed). 2017. *Biology, Physiology and Molecular Biology of Weeds*. CRC Press
- Monaco TJ, Weller SC and Ashton FM. 2014. *Weed Science Principles and Practices*, Wiley
- Powles SB and Shaner DL. 2001. Herbicide Resistance and World Grains, CRC Press.
- Walia US. 2006. *Weed Management*, Kalyani.
- Zimdahl RL. (ed). 2018. *Integrated Weed Management for Sustainable Agriculture, B. D. Sci. Pub.*

I. Course Title : Principles and Practices of Water Management

II. Course Code : Agron 504

III. Credit Hours : 2+1

IV. Aim of the course

To teach the principles of water management and practices to enhance the water productivity

V. Theory

Unit I

Water and its role in plants; Irrigation: Definition and objectives, water resources and irrigation development in of India and concerned state, major irrigation projects, extent of area and crops irrigated in India and in different states.

Unit II

Field water cycle, water movement in soil and plants; transpiration; soil-water-plant relationships; water absorption by plants; plant response to water stress, crop plant adaptation to moisture stress condition. Water availability and its relationship with nutrient availability and loses.

Unit III

Soil, plant and meteorological factors determining water needs of crops, scheduling, depth and methods of irrigation; micro irrigation systems; deficit irrigation; fertigation; management of water in controlled environments and polyhouses. Irrigation efficiency and water use efficiency.

Unit IV

Water management of crop and cropping system, Quality of irrigation water and management of saline water for irrigation, water use efficiency, Crop water requirement- estimation of ET and effective rainfall; Water management of the major crops and cropping systems. Automated irrigation system.

Unit V

Excess of soil water and plant growth; water management in problem soils, drainage requirement of crops and methods of field drainage, their layout and spacing; rain water management and its utilization for crop production.

Unit VI

Quality of irrigation water and management of saline water for irrigation, water management in problem soils

Unit VII

Soil moisture conservation, water harvesting, rain water management and its utilization for crop production.

Unit VIII

Hydroponics,

Unit IX

Water management of crops under climate change scenario.

VI. Practical

- Determination of Field capacity by field method
- Determination of Permanent Wilting Point by sunflower pot culture technique
- Determination of Field capacity and Permanent Wilting Point by Pressure Plate Apparatus
- Determination of Hygroscopic Coefficient
- Determination of maximum water holding capacity of soil
- Measurement of matric potential using gauge and mercury type tensiometer
- Determination of soil-moisture characteristics curves
- Determination of saturated hydraulic conductivity by constant and falling head method
- Determination of hydraulic conductivity of saturated soil below the water table by auger hole method
- Measurement of soil water diffusivity
- Estimation of unsaturated hydraulic conductivity

- Estimation of upward flux of water using tensiometer and from depth ground water table
- Determination of irrigation requirement of crops (calculations)
- Determination of effective rainfall (calculations)
- Determination of ET of crops by soil moisture depletion method16. Determination of water requirements of crops
- Measurement of irrigation water by volume and velocity-area method
- Measurement of irrigation water by measuring devices and calculation of irrigation efficiency
- Determination of infiltration rate by double ring infiltrometer

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Basic knowledge on water management for optimization of crop yield

IX. Suggested Reading

- Majumdar DK. 2014. *Irrigation Water Management: Principles and Practice*. PHL Learning private publishers
- Mukund Joshi. 2013. *A Text Book of Irrigation and Water Management Hardcover*, Kalyani publishers
- Lenka D. 1999. *Irrigation and Drainage*. Kalyani.
- Michael AM. 1978. *Irrigation: Theory and Practice*. Vikas Publ.
- Paliwal KV. 1972. *Irrigation with Saline Water*. IARI Monograph, New Delhi.
- Panda SC. 2003. *Principles and Practices of Water Management*. Agrobios.
- Prihar SS and Sandhu BS. 1987. *Irrigation of Food Crops - Principles and Practices*. ICAR.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani.
- Singh Pratap and Maliwal PL. 2005. *Technologies for Food Security and Sustainable Agriculture*. Agrotech Publ.

I. Course Title : Conservation Agriculture

II. Course Code : Agron 505

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge of conservation of agriculture for economic development.

V. Theory

Unit I

Conventional and conservation agriculture systems, sustainability concerns, conservation agriculture: Historical background and present concept, global experiences, present status in India.

Unit II

Nutrient management in CA, water management, weed management, energy use, insect-pest and disease management, farm machinery, crop residue management, cover crop management.

Unit III

Climate change mitigation and CA, C-sequestration, soil health management, soil microbes and CA.

Unit IV

CA in agroforestry systems, rainfed / dryland regions

Unit V

Economic considerations in CA, adoption and constraints, CA: The future of agriculture

VI. Practicals

- Study of long-term experiments on CA,
- Evaluation of soil health parameters,
- Estimation of C-sequestration,
- Machinery calibration for sowing different crops, weed seedbank estimation under CA, energy requirements, economic analysis of CA.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of various types of conservation of agriculture.

IX. Suggested Reading

- Arakeri HR and Roy D. 1984. *Principles of Soil Conservation and Water Management*. Oxford & IBH.
- Bisht JK, Meena VS, Mishra PK and Pattanayak A. 2016. Conservation Agriculture-An approach to combat climate change in Indian Himalaya. Publisher: Springer Nature. Doi: 10/1007/978-981-10-2558-7.
- Dhruvanarayana VV. 1993. *Soil and Water Conservation Research in India*. ICAR.
- FAO. 2004. *Soil and Water Conservation in Semi-Arid Areas. Soils Bull.,* Paper 57.
- Gracia-Torres L, Benites J, Martinez-Vilela A and Holgado-Cabera A. 2003. Conservation Agriculture- Environment Farmers experiences, innovations Socio-economic policy.
- Muhammad F and Kamdambot HMS. 2014. Conservation Agriculture. Publisher: Springer Cham Heidelberg, New Yaork Dordrecht London. Doi: 10.1007/978-3-319-11620-4.
- Yellamanda Reddy T and Sankara Reddy GH. 1992. *Principles of Agronomy*. Kalyani.

I. Course Title : Agronomy of Major Cereals and Pulses

II. Course Code : Agron 506

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge of crop husbandry of cereals and pulse crops.

V. Theory

Origin and history, area and production, classification, improved varieties, adaptability, climate, soil, water and cultural requirements, nutrition, quality components, handling and processing of the produce for maximum production of:

Unit I: *Rabi* cereals.

Unit II: *Kharif* cereals.

Unit III: *Rabi* pulses.

Unit IV: *Kharif* pulses.

VI. Practical

- Phenological studies at different growth stages of crop
- Estimation of crop yield on the basis of yield attributes
- Formulation of cropping schemes for various farm sizes and calculation of cropping and rotational intensities
- Working out growth indices (CGR, RGR, NAR, LAI, LAD, LAR, LWR, SLA, SLW etc)
- Assessment of land use and yield advantage (Rotational intensity, Cropping intensity, Diversity Index, Sustainable Yield Index Crop Equivalent Yield, Land Equivalent ration, Aggressiveness, Relative Crowding Coefficient, Competition Ratio and ATER etc)
- Estimation of protein content in pulses
- Planning and layout of field experiments
- Judging of physiological maturity in different crops
- Intercultural operations in different crops
- Determination of cost of cultivation of different crops
- Working out harvest index of various crops
- Study of seed production techniques in selected crops
- Visit of field experiments on cultural, fertilizer, weed control and water management aspects
- Visit to nearby villages for identification of constraints in crop production

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on cereals and pulse growing in the country .

IX. Resources

- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Hunsigi G and Krishna KR. 1998. *Science of Field Crop Production*. Oxford & IBH.
- Jeswani LM and Baldev B. 1997. *Advances in Pulse Production Technology*.ICAR.
- Khare D and Bhale MS. 2000. *Seed Technology*. Scientific Publ.
- Kumar Ranjeet and Singh NP. 2003. *Maize Production in India: Golden Grain in Transition*. IARI, New Delhi.
- Pal M, Deka J and Rai RK. 1996. *Fundamentals of Cereal Crop Production*.Tata McGraw Hill.
- Prasad Rajendra. 2002. *Text Book of Field Crop Production*. ICAR.
- Singh C, Singh P and Singh R. 2003. *Modern Techniques of Raising FieldCrops*. Oxford & IBH.
- Singh SS. 1998. *Crop Management*. Kalyani.
- Yadav DS. 1992. *Pulse Crops*. Kalyani.

I. Course Title : Agronomy of Oilseed, Fibre and Sugar Crops
II. Course Code : Agron 507
III. Credit Hours : 2+1

IV. Aim of the course

To teach the crop husbandry of oilseed, fiber and sugar crops

V. Theory

Origin and history, area and production, classification, improved varieties, adaptability, climate, soil, water and cultural requirements, nutrition, quality component, handling and processing of the produce for maximum production of:

Unit I

Rabi oilseeds – Rapeseed and mustard, Linseed and Niger

Unit II

Kharif oilseeds - Groundnut, Sesame, Castor, Sunflower, Soybean and Safflower

Unit III

Fiber crops - Cotton, Jute, Ramie and Mesta.

Unit IV

Sugar crops – Sugar-beet and Sugarcane.

VI. Practical

- Planning and layout of field experiments
- Cutting of sugarcane setts, its treatment and methods of sowing, tying and propping of sugarcane
- Determination of cane maturity and calculation on purity percentage, recovery percentage and sucrose content in cane juice phenological studies at different growth stages of crop
- Intercultural operations in different crops
- Cotton seed treatment
- Working out growth indices (CGR, RGR, NAR, LAI, LAD, LAR, LWR, SLA, SLW etc)
- Assessment of land use and yield advantage (Rotational intensity, Cropping intensity, Diversity Index, Sustainable Yield Index Crop Equivalent Yield, Land Equivalent ration, Aggressiveness, Relative Crowding Coefficient, Competition Ratio and ATER etc)
- Judging of physiological maturity in different crops and working out harvest index
- Working out cost of cultivation of different crops
- Estimation of crop yield on the basis of yield attributes
- Formulation of cropping schemes for various farm sizes and calculation of cropping and rotational intensities
- Determination of oil content in oilseeds and computation of oil yield
- Estimation of quality of fibre of different fibre crops
- Study of seed production techniques in various crops
- Visit of field experiments on cultural, fertilizer, weed control and water management aspects
- Visit to nearby villages for identification of constraints in crop production

VIII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

IX. Learning outcome

Basic knowledge on production of oil seed, sugar and fibre crops.

X. Suggested Reading

- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Das PC. 1997. *Oilseed Crops of India*. Kalyani.
- Lakshmikantam N. 1983. *Technology in Sugarcane Growing*. 2nd Ed. Oxford & IBH.
- Prasad Rajendra. 2002. *Text Book of Field Crop Production*. ICAR.

- Singh C, Singh P & Singh R. 2003. *Modern Techniques of Raising FieldCrops*. Oxford & IBH.
- Singh SS. 1998. *Crop Management*. Kalyani.

I. Course Title : Agronomy of Medicinal, Aromatic and Under Utilized Crops

II. Course Code : Agron 508/PSMA 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about different medicinal, aromatic and underutilized field crops, their package of practices and processing.

V. Theory

Unit I

Importance of medicinal and aromatic plants in human health, national economy and related industries, classification of medicinal and aromatic plants according to botanical characteristics and their uses, export potential and indigenous technical knowledge.

Unit II

Climate and soil requirements; cultural practices; yield and important constituents of medicinal plants (Mulhati, Isabgol, Rauwolfia, Poppy, *Aloe vera*, Satavar, *Stevia*, Safed Musli, Kalmegh, Asaphoetida, *Nuxvomica*, Rosadle, etc).

Unit III

Climate and soil requirements; cultural practices; yield and important constituents of aromatic plants (Citronella, Palmarosa, Mentha, Basil, Lemon grass, Rose, Patchouli, Geranium).

Unit IV

Climate and soil requirements; cultural practices; yield of under-utilized crops (Rice bean, Lathyrus, Sesbania, Clusterbean, French bean, Fenugreek, Grain Amaranth, Coffee, Tea and Tobacco).

Unit V

Post harvest handling –drawing, processing, grading, packing and storage, value addition and quality standards in herbal products.

VI. Practical

- Identification of crops based on morphological and seed characteristics
- Raising of herbarium of medicinal, aromatic and under-utilized plants
- Quality characters in medicinal and aromatic plants
- Methods of analysis of essential oil and other chemicals of importance in medicinal and aromatic plants.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Acquainted with various MAP and their commercial base for developing entrepreneurship.

IX. Suggested Reading

- Chadha KL and Gupta R. 1995. *Advances in Horticulture*. Vol. II. *Medicinal and Aromatic Plants*. Malhotra Publ.
- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Handa SS. 1984. *Cultivation and Utilization of Medicinal Plants*. RRL, CSIR, Jammu.
- Hussain A. 1984. *Essential Oil Plants and their Cultivation*. CIMAP, Lucknow.
- Hussain A. 1993. *Medicinal Plants and their Cultivation*. CIMAP, Lucknow.
- ICAR 2006. *Hand Book of Agriculture*. ICAR, New Delhi.
- Kumar N, Khader Md. Abdul, Rangaswami JBM & Irulappan 1997. *Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants*. Oxford & IBH.
- Prajapati ND, Purohit SS, Sharma AK and Kumar T. 2003. *A Hand Book of Medicinal Plants: A Complete Source Book*. Agrobios.
- Sharma R. 2004. *Agro-Techniques of Medicinal Plants*. Daya Publ. House.

I. Course Title : Agronomy of Fodder and Forage Crops

II. Course Code : Agron 509

III. Credit Hours : 2+1

IV. Aim of the course

To teach the crop husbandry of different forage and fodder crops along with their processing.

V. Theory

Unit I

Adaptation, distribution, varietal improvement, agro-techniques and quality aspects including anti-quality factors of important fodder crops like sorghum, maize, *bajra*, *guar*, cowpea, oats, barley, berseem, *senji*, lucerne, etc.

Unit II

Adaptation, distribution, varietal improvement, agro-techniques and quality aspects including anti-quality factors of important forage crops/grasseslime, Napier grass, *Panicum, Lasiuras, Cenchrus,* etc.

Unit III

Year-round fodder production and management, preservation and utilization of forage and pasture crops.

Unit IV

Principles and methods of hay and silage making; chemical and biochemical changes, nutrient losses and factors affecting quality of hay and silage; use of physical and chemical enrichments and biological methods for improving nutrition; value addition of poorquality fodder. Fodder production through hydroponics. Azolla cultivation.

Unit V

Economics of forage cultivation uses and seed production techniques of important fodder crops.

VI. Practical

- Practical training of farm operations in raising fodder crops;
- Canopy measurement, yield, Leaf: Stem ratio and quality estimation, viz. crude protein, NDF, ADF, lignin, silica, cellulose and IVDMD, etc. of various fodder and forage crops

- Anti-quality components like HCN in sorghum and such factors in other crops
- Hay and silage making and economics of their preparation.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Acquainted with various fodder and forage crops and their commercial base for developing entrepreneurship.

IX. Suggested Reading

- Chatterjee BN. 1989. *Forage Crop Production - Principles and Practices*. Oxford & IBH.
- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Narayanan TR and Dabadghao PM. 1972. *Forage Crops of India*. ICAR.
- Singh P and Srivastava AK. 1990. *Forage Production Technology*. IGFRI, Jhansi.
- Singh C, Singh P and Singh R. 2003. *Modern Techniques of Raising Field Crops*. Oxford & IBH.
- Tejwani KG. 1994. *Agroforestry in India*. Oxford & IBH.

I. Course Title : Agrostology and Agro-forestry
(To be taught jointly by Agronomy and Forestry)

II. Course Code : Agron 510

III. Credit Hours : 2+1

IV. Theory

V. Aim of the course

To teach crop husbandry of different forage, fodder and agroforestry crops/trees along with their processing.

Unit I

Agrostology: definition and importance; principles of grassland ecology: grassland ecology – community, climax, dominant species, succession, biotype, ecological status of grasslands in India, grass cover of India; problems and management of grasslands.

Unit II

Importance, classification (various criteria), scope, status and research needs of pastures; pasture establishment, their improvement and renovation-natural pastures, cultivated pastures; common pasture grasses.

Unit III

Agroforestry: definition and importance; agroforestory systems, agrisilviculture, silvipasture, agrisilvipasture, agrihorticulture, aquasilviculture, alley cropping and energy plantation.

Unit IV

Crop production technology in agro-forestory and agrostology system; silvipastoral system: meaning and importance for wasteland development; selection of species, planting methods and problems of seed germination in agro-forestry systems; irrigation and manuring in agro-forestry systems, associative influence in relation to above ground and underground interferences; lopping and coppicing in agro-forestry systems; social acceptability and economic viability, nutritive value of trees; tender operation; desirable tree characteristics.

VI. Practical

- Preparation of charts and maps of India showing different types of pastures and agro-forestry systems
- Identification of seeds and plants of common grasses, legumes and trees of economic importance with reference to agro-forestry
- Seed treatment for better germination of farm vegetation
- Methods of propagation/ planting of grasses and trees in silvipastoral system
- Fertilizer application in strip and silvipastroal systems
- After-care of plantation
- Estimation of protein content in loppings of important fodder trees
- Estimation of calorie value of wood of important fuel trees
- Estimation of total biomass and fuel wood
- Economics of agro-forestry
- Visit to important agro-forestry research stations

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Basic knowledge on agro forestry, forage crops and their utility

IX. Suggested Reading

- Chatterjee BN and Das PK. 1989. *Forage Crop Production. Principles and Practices.* Oxford & IBH.
- Dabadghao PM and Shankaranarayan KA. 1973. *The Grass Cover in India.* ICAR.
- Dwivedi AP. 1992. *Agroforestry- Principles and Practices.* Oxford & IBH.
- Indian Society of Agronomy. 1989. *Agroforestry System in India. Research and Development,* New Delhi.
- Narayan TR and Dabadghao PM. 1972. *Forage Crop of India.* ICAR, New Delhi.

I. Course Title : Cropping Systems and Sustainable Agriculture

II. Course Code : Agron 511

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint the students about prevailing cropping systems in the country and practices to improve their productivity.

V. Theory

Unit I

Cropping systems: definition, indices and its importance; physical resources, soil and water management in cropping systems; assessment of land use.

Unit II

Concept of sustainability in cropping systems and farming systems, scope and objectives; production potential under monoculture cropping, multiple cropping, alley cropping, sequential cropping and intercropping, mechanism of yield advantage in intercropping systems.

Unit III

Above and below ground interactions and allelopathic effects; competition relations; multi-storied cropping and yield stability in intercropping, role of non-monetary inputs and low cost technologies; research need on sustainable agriculture.

Unit IV

Crop diversification for sustainability; role of organic matter in maintenance of soil fertility; crop residue management; fertilizer use efficiency and concept of fertilizer use in intensive cropping system. Advanced nutritional tools for big data analysis and interpretation.

Unit V

Plant ideotypes for drylands; plant growth regulators and their role in sustainability.

Unit VI

Artificial Intelligence- Concept and application.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, assignment.

VIII. Learning outcome

Basic knowledge on cropping system for sustainable agriculture.

IX. Suggested Reading

- Panda SC. 2017. *Cropping Systems and Sustainable Agriculture*. Agrobios (India)
- Panda SC. 2018. *Cropping and Farming Systems*. Agrobios.
- Palaniappan SP and Sivaraman K. 1996. *Cropping Systems in the Tropics; Principles and Management*. New Age.
- Panda SC. 2003. *Cropping and Farming Systems*. Agrobios.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani.
- Sankaran S and Mudaliar TVS. 1997. *Principles of Agronomy*. The Bangalore Printing & Publ. Co.
- Singh SS. 2006. *Principles and Practices of Agronomy*. Kalyani.
- Tisdale SL, Nelson WL, Beaton JD and Havlin JL. 1997. *Soil Fertility and Fertilizers*. Prentice Hall.

I. Course Title : Dryland Farming and Watershed Management

II. Course Code. : Agron 512

III. Credit Hours : 2+1

IV. Aim of the course

To teach the basic concepts and practices of dry land farming and soil moisture conservation.

V. Theory

Unit I

Definition, concept and characteristics of dry land farming; dry land versus rainfed farming; significance and dimensions of dry land farming in Indian agriculture.

Unit II

Soil and climatic parameters with special emphasis on rainfall characteristics; constraints limiting crop production in dry land areas; types of drought, characterization of environment for water availability; crop
planning for erratic and aberrant weather conditions.

Unit III

Stress physiology and resistance to drought, adaptation of crop plants to drought,

drought management strategies; preparation of appropriate crop plans for dry land areas; mid contingent plan for aberrant weather conditions.

Unit IV

Tillage, tilth, frequency and depth of cultivation, compaction in soil tillage; concept of conservation tillage; tillage in relation to weed control and moisture conservation; techniques and practices of soil moisture conservation (use of mulches, kinds, effectiveness and economics); antitranspirants; soil and crop management techniques, seeding and efficient fertilizer use.

Unit V

Concept of watershed resource management, problems, approach and components.

VI. Practical

- Method of Seed Priming
- Determination of moisture content of germination of important dryland crops
- Determination of Relative Water Content and Saturation Deficit of Leaf
- Moisture stress effects and recovery behaviour of important crops
- Estimation of Potential ET by Thornthwaite method
- Estimation of Reference ET ny Penman Monteith Method
- Classification of climate by Thornthwaite method (based on moisture index, humidity index and aridity index)
- Classification of climate by Koppen Method
- Estimation of water balance by Thornthwaite method
- Estimation of water balance by FAO method
- Assessment of drought
- Estimation of length of growing period
- Estimation of probability of rain and crop planning for different drought condition
- Spray of anti-transpirants and their effect on crops
- Water use efficiency
- Visit to dryland research stations and watershed projects

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment.

VIII. Learning outcome

Basic knowledge on dry land farming and soil moisture conservation.

IX. Suggested Reading

- Reddy TY. 2018. *Dryland Agriculture Principles and Practices*, Kalyani publishers
- Das NR. 2007. *Tillage and Crop Production*. Scientific Publ.
- Dhopte AM. 2002. *Agrotechnology for Dryland Farming*. Scientific Publ.
- Dhruv Narayan VV. 2002. *Soil and Water Conservation Research in India*. ICAR.
- Gupta US. (Ed.). 1995. *Production and Improvements of Crops forDrylands*. Oxford & IBH.
- Katyal JC and Farrington J. 1995. *Research for Rainfed Farming*. CRIDA.
- Rao SC and Ryan J. 2007. *Challenges and Strategies of Dryland Agriculture*. Scientific Publ.
- Singh P and Maliwal PL. 2005. *Technologies for Food Security and Sustainable Agriculture*. Agrotech Publ. Company.
- Singh RP. 1988. *Improved Agronomic Practices for Dryland Crops*. CRIDA.
- Singh RP. 2005. *Sustainable Development of Dryland Agriculture in India*. Scientific Publ.
- Singh SD. 1998. *Arid Land Irrigation and Ecological Management*. Scientific Publ.
- Venkateshwarlu J. 2004. *Rainfed Agriculture in India. Research and Development Scenario*. ICAR.

I. Course Title : Principles and Practices of Organic Farming

II. Course Code : Agron 513

III. Credit Hours : 2+1

IV. Aim of the course

To study the principles and practices of organic farming for sustainable crop production.

V. Theory

Unit I

Organic farming - concept and definition, its relevance to India and global agriculture and future prospects; principles of organic agriculture; organics and farming standards; organic farming and sustainable agriculture; selection and conversion of land, soil and water management - land use, conservation tillage; shelter zones, hedges, pasture management, agro-forestry.

Unit II

Organic farming and water use efficiency; soil fertility, nutrient recycling, organic residues, organic manures, composting, soil biota and decomposition of organic residues, earthworms and vermicompost, green manures, bio-fertilizers and biogas technology.

Unit III

Farming systems, selection of crops andcrop rotations, multiple and relay cropping systems, intercropping in relation to maintenance of soil productivity.

Unit IV

Control of weeds, diseases and insect pest management, biological agents and pheromones, bio-pesticides.

Unit V

Socio-economic impacts; marketing and export potential: inspection, certification, labeling and accreditation procedures; organic farming and national economy.

VI. Practical

- Method of making compost by aerobic method
- Method of making compost by anaerobic method
- Method of making vermicompost
- Identification and nursery raising of important agro-forestry tress and tress for shelter belts
- Efficient use of biofertilizers, technique of treating legume seeds with *Rhizobium* cultures, use of *Azotobacter*, *Azospirillum*, and PSB cultures in field
- Visit to a biogas plant
- Visit to an organic farm
- Quality standards, inspection, certification and labeling and accreditation procedures for farm produce from organic farms

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment. exposure visit

VIII. Learning outcome

Basic knowledge on organic farming for sustainable agriculture and development of entrepreneurship on organic inputs.

IX. Suggested Reading

- Ananthakrishnan TN. (Ed.). 1992. *Emerging Trends in Biological Control of Phytophagous Insects*. Oxford & IBH.
- Gaur AC. 1982. *A Manual of Rural Composting*, FAO/UNDP Regional Project Document, FAO.
- Joshi M. 2016. *New Vistas of Organic Farming*. Scientific Publishers
- Lampin N. 1990. *Organic Farming*. Press Books, lpswitch, UK.
- Palaniappan SP and Anandurai K. 1999. *Organic Farming – Theory and Practice*. Scientific Publ.
- Rao BV Venkata. 1995. *Small Farmer Focused Integrated Rural Development: Socio-economic Environment and Legal Perspective*: Publ.3, ParisaraprajnaParishtana, Bangalore.
- Reddy MV. (Ed.). 1995. *Soil Organisms and Litter Decomposition in the Tropics*. Oxford & IBH.
- Sharma A. 2002. *Hand Book of Organic Farming*. Agrobios.
- Singh SP. (Ed.). 1994. *Technology for Production of Natural Enemies*. PDBC, Bangalore.
- Subba Rao NS. 2002. *Soil Microbiology*. Oxford & IBH.
- Trivedi RN. 1993. *A Text Book of Environmental Sciences*, Anmol Publ.
- Veeresh GK, Shivashankar K and Suiglachar MA. 1997. *Organic Farming and Sustainable Agriculture*. Association for Promotion of Organic Farming, Bangalore.
- WHO. 1990. *Public Health Impact of Pesticides Used in Agriculture*. WHO.
- Woolmer PL and Swift MJ. 1994. *The Biological Management of Tropical Soil Fertility*. TSBF & Wiley.

Course Title with Credit Load
Ph.D. in Agronomy

Course Code	Course Title	Credit Hours
Agron 601*	Current trends in Agronomy	3+0
Agron 602	Recent trends in crop growth and productivity	2+1
Agron 603	Irrigation management	2+1
Agron 604	Recent trends in weed management	2+0
Agron 605	Integrated farming systems for sustainable Agriculture	2+0
Agron 606	Soil Conservation and Watershed Management	2+1
Agron 607	Stress Crop Production	2+1
Agron 608*	Research and Publication ethics	2+0
Agron-691	Doctoral Seminar	1+0
Agron 692	Doctoral Seminar	1+0
Agron 699	Doctoral Research	75

*Indicates Core course for Ph.D.

Course Contents
Ph.D. in Agronomy

I. Course Title : Current Trends in Agronomy
II. Course Code : Agron 601
III. Credit Hours : 3+0

IV. Aim of the course

To acquaint the students about recent advances in agricultural production.

V. Theory

Unit I

Agro-physiological basis of variation in yield, recent advances in soilplant-water relationship.

Unit II

Globalization of agriculture and WTO, precision agriculture, contract farming, organic farming, marketing and export potential of organic products, certification, labeling and accreditation procedures and ITK in organic farming.

Unit III

Crop residue management in multiple cropping systems; latest developments in plant managementMechanizationin crop production: modern agricultural precision tools and technilogies, weed management, cropping systems, grassland management, agro-forestry, allelopathy.

Unit IV

GIS, GPS and remote sensing for crop management, global warming, GM crops, seed production technology; seed certification, seed multiplication, hybrid seed production etc.

Unit V

Concepts of system agriculture; holistic approach of farming systems, dryland farming, sustainable agriculture and research methodology in Agronomy. Conservation agriculture, principles, prospects and importance, potential benefits of CA under climate change scenario, policy issues.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Recent advances in agricultural production

VIII. Suggested Reading

- Agarwal RL. 1995. *Seed Technology*. Oxford & IBH.
- Dahiya BS and Rai KN. 1997. *Seed Technology*. Kalyani.
- Govardhan V. 2000. *Remote Sensing and Water Management in Command Areas: Agroecological Prospectives*. IBDC.

- ICAR. 2006. *Hand Book of Agriculture*. ICAR.
- Narasaiah ML. 2004. *World Trade Organization and Agriculture*. Sonali Publ.
- Palaniappan SP and Annadurai K. 2006. *Organic Farming - Theory and Practice*. Scientific Publ.
- Sen S and Ghosh N. 1999. *Seed Science and Technology*. Kalyani.
- Tarafdar JC, Tripathi KP and Kumar M. 2007. *Organic Agriculture* Scientific Publ.
- Kumar, R, Swarnkar KS, Singh KS and Narayan S. 2016. *A Text Book of Seed Technology*. Kalyani Publication.
- Reddy SR and Prabhakara G. 2015. *Dryland Agriculture*. Kalyani Publishers.
- Gururajan B, Balasubhramanian R and Swaminath V. 2013. *Recent Strategies on Crop Production*. Kalyani Publishers.
- Venkateswarlu B and Shanker Arun K. 2009. *Climate change and agriculture: Adaptation and mitigation strategies*. *Indian Journal of Agronomy* **54**(2): 226-230.

I. Course Title : Recent Trends in Crop Growth and Productivity

II. Course Code : Agron 602

III. Credit Hours : 2+1

IV. Aim of the course

To study the physiology of vegetative and reproductive growth in relation to productivity of different crops in various environments.

V. Theory

Unit I

Plant density and crop productivity; plant and environmental factors, yield, plant distribution, strategies for maximizing solar energy utilization; leaf area; interception of solar radiation and crop growth; photosynthesis: the photosynthetic apparatus, factors essential for photosynthesis; difference in photosynthetic rates among and within species; physiological limitations to crop yield; solar radiation concept and agro-techniques for harvesting solar radiation.

Unit II

Growth analysis: concept, CGR, RGR, NAR, LAI, LAD, LAR; validity and Limitations in interpreting crop growth and development; growth curves: sigmoid, polynomial and asymptotic; root systems; root-shoot relationship; principles involved in inter and mixed cropping systems under rainfed and irrigated conditions; concept and differentiation of inter and mixed cropping; criteria in assessing the yield advantages.

Unit III

Competitive relationship and competition functions; biological and agronomic basis of yield advantage under intercropping; physiological principles of dry land crop production, constraints and remedial measures; heat unit concept of crop maturity: concept and types of heat units.

Unit IV

Concept of plant ideotypes: crop physiological and new ideotypes; characteristics of ideotype for wheat, rice, maize, etc.; concept and types of growth hormones; their role in field crop production; efficient use of resources.

VI. Practical

- Field measurement of root-shoot relationship in crops at different growth stages
- Estimation of growth evaluating parameters like CGR, RGR, NAR, LAI etc., at

different stages of crop growth
- Computation of harvest index of various crops
- Assessment of crop yield on the basis of yield attributing characters
- Construction of crop growth curves based on growth analysis data
- Computation of competition functions, viz. LER, IER aggressivity competition index etc in intercropping
- Senescence and abscission indices
- Analysis of productivity trend in un-irrigated areas
- Analysis of productivity trend in irrigated areas

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of crop growth for agricultural production

IX. Suggested Reading

- Chopra VL and Paroda RS. 1984. *Approaches for Incorporation of Drought and Salinity Resistance in Crop Plants*. Oxford & IBH.
- Delvin RM and Vitham FH. 1986. *Plant Physiology*. CBS Publ.
- Evans LT. 1975. *Crop Physiology*. Cambridge Univ. Press.
- Evans LT. 1996. *Crop Evolution, Adaptation and Yield*. Cambridge Univ. Press.
- Gupta US. (Ed.). 1995. *Production and Improvement of Crops for Drylands*. Oxford & IBH.
- Gupta US. 1988. *Progress in Crop Physiology*. Oxford & IBH.
- Kramer PJ and Boyer JS. 1995. *Water Relations of Plant and Soils*. Academic Press.
- Mukherjee S and Ghosh AK. 1996. *Plant Physiology*. Tata McGraw Hill.
- Narwal SS, Politycka B and Goswami CL. 2007. *Plant Physiology: Research Methods*. Scientific Pub.
- Tiaz L. and Zeiger E. 2006. Plant Physiology. Sinauer Associates, Inc.

I. Course Title : Irrigation Management

II. Course Code : Agron 603

III. Credit Hours : 2+1

IV. Aim of the course

To teach students about optimization of irrigation in different crops under variable agro climatic conditions.

V. Theory

Unit I

Global water resources; Water resources of India, irrigation projects during pre and post independence period and their significance in crop production; irrigation needs, atmospheric, soil, agronomic, plant and water factors affecting irrigation need; water deficits and crop growth.

Unit II

Movement of water in soil-water movement under saturated and unsaturated conditions, Poiseulle's and Darcy's law, general equation of saturated and unsaturated flow of water in soil.

Soil-plant-water relationships, evaporation, transpiration and evapotranspiration, significance of transpiration, energy utilization in transpiration, physiological processes and crop productivity.

Unit III

Water requirement, irrigation needs, factors affecting irrigation need; water use efficiency, Infiltration; water movement under saturated and unsaturated conditions; management practices for improving water use efficiency of crops.

Unit IV

Soil and plant water potential, SPAC, transpiration and evapotranspiration, significance of transpiration, energy utilization in transpiration, factors affecting ET, control of ET by mulching and use of anti-transpirents; fertilizer use in relation to irrigation.

Unit V

Crop water stress – water deficits and crop growth, adoptability to the crops. Water availability with relation to nutrient availability.

Unit VI

Application of irrigation water, conveyance and distribution system, irrigation efficiency; agronomic considerations in the design and operation of irrigation projects; characteristics of irrigation and farming systems affecting irrigation management.

Unit VII

Strategies of using limited water supply; factors affecting ET, control of ET by mulching and use of anti-transpirants; fertilizer use in relation to irrigation; optimizing the use of given irrigation supplies.

Unit VIII

Land suitability for irrigation, land irrigability classification; integrated water management in command areas, institution of water management in commands, farmer's participation in command areas; irrigation legislation.

Unit IX

Economic analysis of irrigation and cop planning for optimum use of irrigation water

Unit X

Crop water production function

VI. Practical

- Determination of water infiltration characteristics and water holding capacity of soil profiles.
- Determination Moisture extraction pattern of crops
- Determination of water balance component of transplanted rice by drum culture technique
- Determination of consumptive use and water requirement of a given cropping pattern
- Determination of crop efficient of one important crop
- Planning, designing and installation of drip irrigation system
- Planning, designing and installation of sprinkler irrigation system
- Designing of drainage channel
- Measurement of irrigation efficiencies
- Determination of irrigation timing under different methods of irrigation
- Visit to irrigation command area

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Management of irrigation water for sustainable agriculture

IX. Suggested Reading

- MP. Singh 2017. Recent advances in Irrigation water management. Kalyani Publishers
- FAO. 1984. *Irrigation Practice and Water Management*. Oxford & IBH.
- Michael AM. 1978. *Irrigation: Theory and Practice*. Vikas Publ.
- Mishra RR and Ahmad M. 1987. *Manual on Irrigation and Agronomy*. Oxford & IBH.
- Panda SC. 2003. *Principles and Practices of Water Management*. Agrobios.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani.
- Sankara Reddy GH and Yellamananda Reddy. 1995. Efficient Use of Irrigation Water. In: Gupta US. (Ed.). *Production and Improvement of Crops for Drylands*. Oxford & IBH.
- Singh SS. 2006. Principles and Practices of Agronomy. In: Gupta US.(Ed.). *Production and Improvement of Crops for Drylands*. Oxford & IBH

I. Course Title : Recent Trends in Weed Management

II. Course Code : Agron 604

III. Credit Hours : 2+0

IV. Aim of the course

To teach about the changing weed flora, new herbicides, their resistance, toxicity, antidotes and residue management under different cropping systems.

V. Theory

Unit I

Crop-weed competition in different cropping situations; changes in weed flora, various causes and effects; different methods of weed management. Migration, introduction, adaptation of weeds, Invasive weeds – biology and management. Different mechanisms of invasion – present status and factors influencing weed invasion.

Unit II

Physiological and biological aspects of herbicides, their absorption, translocation, metabolism and mode of action; selectivity of herbicides and factors affecting them.

Unit III

Climatic factors and phytotoxicity of herbicides; fate of herbicides in soil and factors affecting them, Degradation of herbicides in soil and plants- factors affecting it, primary and secondary metabolites, residue management of herbicides, adjuvants.

Unit IV

Advances in herbicide products and application techniques and methods; herbicide resistance; antidotes and crop protection compatibility of herbicides of different groups; compatibility of herbicides with other pesticides; herbicide rotation and herbicide mixtures.

Unit V

Development of transgenic herbicide resistant crops; herbicide development, registration procedures.

Unit VI

Relationship of herbicides with tillage, fertilizer, and irrigation, cropping system; bioherbicides, allelochemical and alleloherbicides, herbicide bioassays. Recent advances in nonchemical weed management including deleterious rhizobacteria, robotics, biodegradable film, etc.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of new herbicides, their resistance, toxicity, antidotes and residue management under different cropping systems.

VIII. Suggested Reading

- Böger, Peter, Wakabayashi, Ko, Hirai, Kenji (Eds.). 2002. *Herbicide Classes in Development. Mode of Action, Targets, Genetic Engineering, Chemistry*. Springer.
- Das TK. 2008. *Weed Science: Basics and Applications*, Jain Brothers (New Delhi)
- Fennimore, Steven A and Bell, Carl. 2014. *Principles of Weed Control*, 4th Ed, California Weed Sci. Soc.
- Gupta OP. 2007. *Weed Management: Principles and Practices*, 2nd Ed.
- Jugulan M, (ed). 2017. *Biology, Physiology and Molecular Biology of Weeds*. CRC Press
- Monaco TJ, Weller SC and Ashton FM. 2014. *Weed Science Principles and Practices*, Wiley
- Powles SB and Shaner DL. 2001. *Herbicide Resistance and World Grains*, CRC Press.
- Walia US. 2006. *Weed Management*, Kalyani.
- Zimdahl RL. (ed). 2018. *Integrated Weed Management for Sustainable Agriculture, B. D. Sci. Pub*

I. Course Title : Integrated Farming Systems and Sustainable Agriculture

II. Course Code : Agron 605

III. Credit Hours : 2+0

IV. Aim of the course

To apprise about different enterprises suitable for different agroclimatic conditions for sustainable agriculture.

V. Theory

Unit I

Integrated Farming systems (IFS): definition, scope and importance; classification of IFS based on enterprises as well as under rainfed/irrigated condition in different land situation. farming systems according to type of rotation, intensity of rotation, degree of commercialization, water supply, enterprises.

Unit II

Concept of sustainability in of Integrated farming systems; efficient Integrated farming systems based on economic viability and natural resources - identification and management.

Unit III

Production potential of different components of Integrated farming systems; interaction and mechanism of different production factors; stability of Integrated Farming system based on research/long term information. in different systems through research; eco-physiological approaches to intercropping. Integration of components and adaptability of different farming system based on land situations and climatic condition of a region; evaluation of IFS.

Unit IV

Simulation models for intercropping; soil nutrient in intercropping; preparation of different farming system models; evaluation of different farming systems. Formation of different Integrated Farming system Models; evaluation of different Integrated Farming system models. Recycling of organic waste in farming system, in IFS.

Unit V

New concepts and approaches of farming system and organic farming; value addition, waste recycling, quantification and mitigation of Green House gases; case studies/ success stories of different Integrated Farming systems. cropping systems and organic farming; case studies on different farming systems. Possible use of ITK in Integrated farming system.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of enterprises suitable for different agroclimatic conditions for sustainable agriculture and their proper utilization .

VIII. Suggested Reading

- Ananthakrishnan TN. (Ed.). 1992. *Emerging Trends in Biological Control of Phytophagous Insects*. Oxford & IBH.
- Baishya A, Borah M, Das AK, Hazarika J, Gogoi B and Borah AS 2017. *Waste Recycling Through Integrated Farming systems. An Assam Agriculture Experience*. Omni Scriptum Gmbh & Co. KG, Germany.
- Balasubramanian P and Palaniappan SP. 2006. *Principles and Practices of Agronomy*. Agrobios.
- Edens T. 1984. *Sustainable agriculture and integrated farming system*. Michigan State Univ. press.
- Jayanthi C. 2006. *Integrated Farming systems-A way to sustainable Agriculture*. Tamil Nadu Agricultural University, Coimbatore
- Joshi M and Parbhakarasetty TK. 2005. *Sustainability through Organic Farming*. Kalyani.
- Kolhapure A and Madhukar D. *A text book of farming system and sustainable agriculture*.
- Palaniappan SP and Anandurai K. 1999. *Organic Farming - Theory and Practice*. Scientific Publ.
- Panda SC. 2004. *Cropping systems and Farming Systems*. Agribios.
- Lampin N. 1990. *Organic Farming*. Farming Press Books.
- Ravisankar D and Jayanthi C. 2015. *Farming systems: concepts and approaches*. Agrobios,

I. Course Title : Soil Conservation and Watershed Management

II. Course Code : Agron 606

III. Credit Hours : 2+1

IV. Aim of the course

To teach about different soil moisture conservation technologies for enhancing the agricultural productivity through holistic approach watershed management.

V. Theory

Unit I

Soil erosion: definition, nature and extent of erosion; types of erosion, factors affecting erosion.

Unit II

Soil conservation: definition, methods of soil conservation; agronomic measures - contour cultivation, strip cropping, cover crops; mulching, tillage, cropping system vegetative barriers; improved dry farming practices; mechanical measures - bunding, gully control, bench terracing; role of grasses and pastures in soil conservation; wind breaks and shelter belts.

Unit III

Watershed management: definition, objectives, concepts, approach, components, steps in implementation of watershed; development of cropping systems for watershed areas.

Unit IV

Land use capability classification, alternate land use systems; agro-forestry; ley farming; *jhum* management - basic concepts, socio-ethnic aspects, its layout.

Unit V

Drainage, methods of drainage, Drainage considerations and agronomic management; rehabilitation of abandoned *jhum* lands and measures to prevent soil erosion.

VI. Practical

- Study of different types of erosion
- Determination of dispersion ratio
- Estimation of soil loss by Universal Soil Loss Equation
- Estimation of soil loss by wind erosion
- Measurement of runoff and soil loss
- Field studies of different soil conservation measures
- Laying out run-off plot and deciding treatments
- Identification of different grasses and trees for soil conservation
- Visit to watershed areas
- Visit to a soil conservation research centre, demonstration and training centre

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil moisture conservation technologies for enhancing the agricultural productivity through holistic approach watershed management.

IX. Suggested Reading

- Arakeri HR and Roy D. 1984. *Principles of Soil Conservation and Water Management*. Oxford & IBH.
- Dhruvanarayana VV. 1993. *Soil and Water Conservation Research in India*. ICAR.
- FAO. 2004. *Soil and Water Conservation in Semi-Arid Areas. Soils Bull.,* Paper 57.
- Frederick RT, Hobbs J, Arthur D and Roy L. 1999. *Soil and Water Conservation: Productivity and Environment Protection.* 3rd Ed. Prentice Hall.

- Gurmel Singh, Venkataraman CG, Sastry B and Joshi P. 1990. *Manual of Soil and Water Conservation Practices*. Oxford & IBH.
- Murthy VVN. 1995. *Land and Water Management Engineering*. Kalyani.
- Tripathi RP and Singh HP. 1993. *Soil Erosion and Conservation*. Wiley Eastern.
- Yellamanda Reddy T and Sankara Reddy GH. 1992. *Principles of Agronomy*. Kalyani.

I. Course Title : Stress Crop Production

II. Course Code : Agron 607

III. Credit Hours : 2+1

IV. Aim of the course

To study various types of stresses in crop production and strategies to overcome them.

V. Theory

Unit I

Stress and strain terminology; nature and stress injury and resistance; causes of stress.

Unit II

Low temperature stress: freezing injury and resistance in plants, measurement of freezing tolerance, chilling injury and resistance in plants, practical ways to overcome the effect of low temperature tress through, soil and crop manipulations.

Unit III

High temperature or heat stress: meaning of heat stress, heat injury and resistance in plants, practical ways to overcome the effect of heat stress through soil and crop manipulations.

Unit IV

Water deficit stress: meaning of plant water deficient stress and its effect on growth and development, water deficit injury and resistance, practical ways to overcome effect of water deficit stress through soil and crop, manipulations.

Unit V

Excess water or flooding stress: meaning of excess water stress, its kinds and effects on crop plants, excess water stress injury and resistance, practical ways to overcome excess water stress through soil and crop manipulations.

Unit VI

Salt stress: meaning of salt stress and its effect on crop growth, salt stress injury and resistance in plants, practical ways to overcome the effect of salt stress through soil and crop manipulations.

Unit VII

Mechanical impedance of soil and its impact on plant growth; measures to overcome soil mechanical impedance.

Unit VIII

Environmental pollution: air, soil and water pollution, and their effect on crop growth and quality of produce; ways and means to prevent environmental pollution.

VI. Practical

- Determination of electrical conductivity of plant cell sap
- Determination of osmotic potential and tissue water potential
- Measurement of transpiration rate
- Measurement of stomatal frequency
- Measurement of Relative Water Content of leaf
- Measurement of electrolytic leakage
- Growing of plants in sand culture under salt stress for biochemical and physiological studies
- Studies on effect of osmotic and ionic stress on seed germination and seedling growth
- Measurement of low temperature injury under field conditions
- Studies on plant responses to excess water.

VIII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

IX. Learning outcome

Experience on the knowledge of various types of stresses in cropproduction and strategies to overcome these.

X. Suggested Reading

- Baker FWG.1989. *Drought Resistance in Cereals*. Oxon, UK.
- Gupta US. (Ed.). 1988. *Physiological Aspects of Dryland Farming*. Oxford & IBH.
- Kramer PJ.1983. *Water Relations of Plants*. Academic Press.
- Levitt J. 1980. *Response of Plants to Environmental Stresses*. Vols. I, II. Academic Press.
- Mavi HS.1978. *Introduction to Agro-meteorology*. Oxford & IBH.
- Michael AM and Ojha TP.1981. *Principles of Agricultural Engineering*. Vol II. Jain Bros.
- Nilsen ET and Orcut DM. 1996. *Physiology of Plants under Stress – Abiotic Factors*. John Wiley & Sons.
- Singh K. 2000. *Plant Productivity under Environmental Stress*. Agribios.
- Singh KN and Singh RP. 1990. *Agronomic Research Towards Sustainable Agriculture*. Indian Society of Agronomy, New Delhi.
- Somani LL and Totawat KL. 1992. *Management of Salt-affected Soils and Waters*. Agrotech Publ.
- Virmani SM, Katyal JC, Eswaran H and Abrol IP. 1994. *Stressed Ecosystem and Sustainable Agriculture*. Oxford & IBH.

I. Title : Research and Publication Ethics

II. Course Code : Agron 608

III. Credit Hours : 0+2

IV. Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit IV

Publication ethics: Defination, introduction and importance. Best practices/standard setting initiatives and guidelines: COPE, WAME, etc., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatorypublishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to checkpublisher copy right and selfarchivingpolicies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools viz., JANE, Elsevier Journal Finder, Springer Journal Suggesteretc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open sourcesoftware tools

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, etc. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index altmetrics.

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field practicals and laboratory visit.

VI. Learning outcome

Developed skill for research management, quality publication.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Soil Science

Preamble

Soils comprise a multiple phase system consisting of numerous solid phases (about 50%), a liquid phase (about 25%) and a gas phase (about 25%). The solids include rock consisting of many different primary and secondary minerals. Superimposed on this inorganic matrix is what Truog (1951) described as the 'living phase' which includes bacteria, fungi, actinomycetes, algae, protozoa, nematodes and other forms of life. These living organisms are continuously breaking down organic residues and synthesizing many of the products into body tissues while others are released to the surroundings Many physical, chemical and biological changes continually take place in soils. Physical processes such as wetting, drying, freezing, thawing changing temperatures and leaching modify the surface areas of soil particles. Primary minerals change to secondary minerals as ionic species in solution seek lower free energy levels. In addition, plants capture energy from sun and store in the form of organic compounds. Because of dynamic nature of soils, various changes take place regularly in soils and therefore, it is very essential to know the behaviour of soil solution, matrix potential so that proper technology can be achieved through research works.

Our knowledge has increased rapidly during the last decade concerning the role of macro and micro nutrients in soils, plants, animal nutrition and in food for man. The skills of several scientific disciplines, combined with sophisticated instruments, have extended our knowledge about nutrients in plants and soils to molecular level and to microenvironments of roots in soil. One of the cherished objectives of the salient feature of the revised syllabi is to foster high standard in education system of soil science. A paradigm shift is necessary in education prioritization to meet the challenges of the present and future in soil science.

Students, therefore have to be acquainted with the modern concepts of different processes, concepts and development so as to develop competencies on the area of specialization of the subject. For the purpose, it is proposed to revise the course syllabus of Soil Science in the light of the present days need incorporating the basic concepts, developments of the discipline.

The existing M.Sc. (Ag) courses of soil science have been modified taking into account of present day need by incorporating the necessary and important topics in the respective courses such as basic principle of physics applied to soils, fertility status of major soil groups of India, Long term effect of manures and fertilizers on soil fertility and crop productivity, Soil health quality in relation to human health, Speciality fertilizers, Concept of quantity/ intensity relationship, Soil mapping, Interaction of clay with humus, pesticides and heavy metals, Soil enzyme, Humus formation, Root rhizosphere and Biodegradation of pesticide. The new topics are covered in Ph.D courses as Soil-plant-atmospheric continuum (SPAC), Kinetics studies of nutrients in soils, Climate change on soil properties and Carbon sequestration. Major changes have been made in some of the existing courses like soil fertility and fertilizer uses, soil biology and biochemistry and Analytical technique and instrumental methods in soil and plant analysis under MSc programme and Biochemistry of soil organic matter under PhD programme. As a part of course curriculum, M. Sc.(Ag) soil science was restructured to equip students to tackle emerging issues by inclusion of two new courses on (i) Soil survey and land use planning (ii) Introduction to nanotechnology. The Ph.D. courses of soil science was revised by adding four important new courses (i) Recent trend in soil microbial diversity (ii) Soil resource management (ii) Modelling of soil plant system (iv) Clay mineralogy.

Course Title with Credit Load
M.Sc. in Soil Science

Course Code	Course Title	Credit Hours
*Soil 501	Soil physics	(2+1)
*Soil 502	Soil fertility and fertilizer use	(2+1)
*Soil 503	Soil chemistry	(2+1)
*Soil 504	Soil mineralogy, genesis and classification	(2+1)
Soil 505	Soil erosion and conservation	(2+1)
Soil 506	Soil Biology and Biochemistry	(2+1)
Soil 507	Radioisotopes in soil and plant studies	(1+1)
Soil 508	Soil, water and air pollution	(2+1)
Soil 509	Remote sensing and GIS technique for soil and crop studies	(2+1)
Soil 510	Analytical technique and instrumental methods in soil and plant analysis	(0+2)
Soil 511	Management of problematic soils and water	(1+1)
Soil 512	Land degradation and restoration	(1+0)
Soil 513	Soil Survey and Land use Planning	(2+0)
Soil 514	Introduction to nanotechnology	(2+1)
Soil 591	Master's Seminar	(1+0)
Soil 599	Master's Research	-30

*Indicates Core Courses which are Compulsory for Master Programme

Course contents
M.Sc. in Soil Science

I. Course Title : Soil Physics
II. Course Code : Soil 501
III. Credit Hours : 2+1

IV. Aim of the course

To impart basic knowledge about soil physical properties and processes in relation to plant growth.

V. Theory

Unit I

Basic principles of physics applied to soils, soil as a three phase system.

Unit II

Soil texture, textural classes, mechanical analysis, specific surface.

Unit III

Soil consistence; dispersion and workability of soils; soil compaction and consolidation; soil strength; swelling and shrinkage - basic concepts.Alleviation of soil physical constraints for crop production. Soil erosion and edibility

Unit IV

Soil structure - genesis, types, characterization and management soil structure; soil

aggregation, aggregate stability; soil tilth, characteristics of good soil tilth; soil crusting -mechanism, factors affecting and evaluation; soil conditioners; puddling, its effect on soil physical properties; clod formation.

Unit V

Soil water: content and potential, soil water retention, soil-water constants, measurement of soil water content, energy state of soil water, soil water potential, soil-moisture characteristic curve; hysteresis, measurement of soil-moisture potential.

Unit VI

Water flow in saturated and unsaturated soils, Poiseuille's law, Darcy's law; hydraulic conductivity, permeability and fluidity, hydraulic diffusivity; measurement ofhydraulic conductivity in saturated and unsaturated soils.

Unit VII

Infiltration; internal drainage and redistribution; evaporation; hydrologic cycle, field water balance; soil-plant-atmosphere continuum.

Unit VIII

Composition of soil air; renewal of soil air - convective flow and diffusion; measurement of soil aeration; aeration requirement for plant growth; soil air management.

Unit IX

Modes of energy transfer in soils; energy balance; thermal properties of soil; measurement of soil temperature; soil temperature in relation to plant growth; soiltemperature management.

VI. Practical

- Determination of B.D, P.D and mass volume relationship of soil, Mechanical analysis by hydrometer and international pipette method,
- Measurement of Atterberg limits, Aggregate analysis - dry and wet, Measurement of soil-water content by different methods, Measurement of soil-water potential by using tensiometer and gypsum Blocks, Determination of soil-moisture characteristics curve and computation of pore-size, distribution, Determination of hydraulic conductivity under saturated and unsaturated conditions, Determination of infiltration rate of soil, Determination of aeration porosity and oxygen diffusion rate, Soil temperature measurements by different methods, Estimation of water balance components in bare and cropped fields.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Baver LD, Gardner WH and Gardner WR. 1972. *Soil Physics*. John Wiley & Sons.
- Ghildyal BP and Tripathi RP. 2001. *Soil Physics*. New Age International.
- Hanks JR and Ashcroft GL. 1980. *Applied Soil Physics*. Springer Verlag.
- Hillel D. 1972. *Optimizing the Soil Physical Environment toward Greater Crop Yields*. Academic Press.
- Hillel D. 1980. *Applications of Soil Physics*. Academic Press.
- Hillel D. 1980. *Fundamentals of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physic*s. Academic Press.
- Hillel D. 2003. *Introduction to Environmental Soil Physics*. Academic Press.
- Indian Society of Soil Science. 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Kirkham D and Powers WL. 1972. *Advanced Soil Physics*. Wiley-Interscience.
- Kohnke H. 1968. *Soil Physics*. McGraw Hill.
- Lal R and Shukla MK. 2004. *Principles of Soil Physics*. Marcel Dekker.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. Course Title : Soil Fertility and Fertilizer Use

II. Course Code : Soil 502

III. Credit Hours : 3+1

IV. Aim of the course

To impart knowledge about soil fertility and its control, and to understand the role of fertilizers and manures in supplying nutrients to plants so as to achieve high fertilizer use efficiency.

V. Theory

Unit I

Soil fertility and soil productivity; fertility status of major soils group of India;

nutrient sources – fertilizers and manures; Criteria of essentiality, classification, law of minimum and maximum, essential plant nutrients - functions and deficiency symptoms, Nutrient uptake, nutrient interactions in soils and plants; long term effect of manures and fertilizers on soil fertility and crop productivity.

Unit II

Soil and fertilizer nitrogen – sources, forms, immobilization and mineralization, nitrification, denitrification; biological nitrogen fixation -types, mechanism, microorganisms and factors affecting; nitrogenous fertilizers and their fate in soils; management of fertilizer nitrogen in lowland and upland conditions for high fertilizer use efficiency.

Unit III

Soil and fertilizer phosphorus - forms, immobilization, mineralization, reactions in acid andalkali soils; factors affecting phosphorus availability in soils; phosphatic fertilizers - behavior in soilsand management under field conditions. Potassium - forms, equilibrium in soils and its agriculturalsignificance; mechanism of potassium fixation; management of potassium fertilizers under fieldconditions.

Unit V

Sulphur - source, forms, fertilizers and their behavior in soils; roleincropsandhuman health; calcium and magnesium– factors affecting their availability in soils; management of sulphur, calcium and magnesium fertilizers.

Unit VI

Micronutrients – critical limits in soils and plants; factors affecting their availability and correction of their deficiencies in plants; role of chelates in nutrient availability.

Unit VII

Common soil test methods for fertilizer recommendations; quantity–intensityrelationships; soil test crop response correlations and response functions.

Unit VIII

Fertilizer use efficiency; site-specific nutrient management; plant need based nutrient management; integrated nutrient management; specialityfertilizersconcept, needand category.CurrentstatusofspecialityfertilizersuseinsoilsandcropsofIndia;

Unit IX

Soil fertility evaluation - biological methods, soil, plant and tissue tests; soilquality in relation to sustainable agriculture, Determination of critical limit, DRIS

Unit X

Definition and concepts of soil health and soil quality; Longterm effects of fertilizers and soil quality.

VI. Practical

- Soil and plant sampling and processing for chemical analysis
- Determination of soil pH, total and organic carbon in soil
- Chemical analysis of soil for total and available nutrients(major and micro)
- Analysis of plants for essential elements(major and micro)

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil fertility and fertilizers in relation to plant growth and development.

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- Kabata-Pendias A and Pendias H. 1992. *Trace Elements in Soils and Plants*. CRC Press.
- Kannaiyan S, Kumar K and Govindarajan K. 2004. *Biofertilizers Technology*. Scientific Publ.
- Leigh J G. 2002. *Nitrogen Fixation at the Millennium*. Elsevier.
- Mengel K and Kirkby EA. 1982. *Principles of Plant Nutrition*. International Potash Institute, Switzerland.
- Mortvedt JJ, Shuman LM, Cox FR and Welch RM. 1991. *Micronutrients in Agriculture*. 2nd Ed. SSSA, Madison.
- Pierzinsky GM, Sims TJ and Vance JF. 2002. *Soils and Environmental Quality*. 2nd Ed. CRC Press.
- Stevenson FJ and Cole MA. 1999. *Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulphur, Micronutrients*. John Wiley & Sons.
- Tisdale SL, Nelson SL, Beaton JD and Havlin JL. 1999. *Soil Fertility and Fertilizers*. 5th Ed. Prentice Hall of India.
- Troeh FR and Thompson LM. 2005. *Soils and Soil Fertility*. Blackwell.

I. Course Title : Soil Chemistry

II. Course Code : Soil 503

III. Credit Hours : 2+1

IV. Suggested Reading

To introduce the classical concepts of soil chemistry and to familiarize students with modern developments in chemistry of soils in relation to using soils as a medium for plant growth.

V. Theory

Unit I

Chemical (elemental) composition of the earth's crust, soils, rocks and minerals

Unit II

Elements of equilibrium thermodynamics, chemical equilibria, electrochemistry and chemical kinetics.

Unit III

Soil colloids: inorganic and organic colloids - origin of charge, concept of point of zero-charge (PZC) and its dependence on variable-charge soil components, surface charge characteristics of soils; diffuse double layer theories of soil colloids, zeta potential, stability, coagulation/flocculation and peptization of soil colloids; electrometric properties of soil colloids; sorption properties of soil colloids; soil organic matter - fractionation of soil organic matter and different fractions, Characterization of OM; clay-organic interactions.

Unit IV

Ion exchange processes in soil; cation exchange- theories based on law of massaction (Kerr-Vanselow, Gapon equations, hysteresis, Jenny's concept), adsorptionisotherms, Donnan-membrane equilibrium concept, clay-membrane electrodes and ionicactivity measurement, thermodynamics, statistical mechanics; anion and ligand exchange–

innersphere and outer-sphere surface complex formation, fixation of oxyanions, hysteresisin sorption-desorption of oxy-anions and anions, shift of PZC on ligand exchange, AEC, CEC; experimental methods to study ion exchange phenomena and practical implications in plant nutrition.

Unit V

Potassium, phosphate and ammonium fixation in soils covering specificand non-specific sorption; precipitation-dissolution equilibria; Conceptof quantity/intensity(Q/I)relationship; step and constant-rate K; managementaspects.

Unit VI

Chemistry of acid soils; active and potential acidity; lime potential, chemistry of acid soils; sub-soil acidity.

Unit VII

Chemistry of salt-affected soils and amendments; soil pH, ECe, ESP, SAR and important relations; soil management and amendments.

Unit VIII

Chemistry and electrochemistry of submerged soils, geochemistry of micronutrients, environmental soil chemistry

VI. Practical

Preparation of saturation extract, measurement of pH, EC, CO, HCO, Ca, Mg, K and Na, Determination of CEC and AEC of soils, Analysis of equilibrium soil solution for pH, EC, Eh by the use of Eh-pH meter andconductivity meter, Determination of point of zero-charge and associated surface charge characteristics by the serial potentiometric titration method, Extraction of humic substances, Potentiometric and conductometric titration of soil humic and fulvic acids, (E4/E6) ratio of soil humic and fulvic acids by visible spectrophotometric studies and the D (E4/E6) values at two pH values, Adsorption-desorption of phosphate/sulphate by soil using simple adsorption isotherm, Construction of adsorption envelope of soils by using phosphate/fluoride/sulphate and ascertaining the mechanism of the ligand exchange process involved, Determination of titratable acidity of an acid soil by BaCl2-TEA method, Determination of Q/I relationship of potassium, Determination of lime requirement of an acid soil by buffer method, Determination of gypsum requirement of an alkali soil.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of chemical behaviour of soil and their utility in research for solving field problem.

IX. Suggested Reading

- Bear RE. 1964. *Chemistry of the Soil*. Oxford and IBH.
- Bolt GH and Bruggenwert MGM. 1978. *Soil Chemistry*. Elsevier.
- Greenland DJ and Hayes MHB. 1981. *Chemistry of Soil Processes*. John Wiley & Sons.
- Greenland DJ and Hayes MHB. *Chemistry of Soil Constituents*. John Wiley & Sons.
- McBride MB. 1994. *Environmental Chemistry of Soils*. Oxford University Press.
- Sposito G. 1981. *The Thermodynamics of Soil Solutions*. Oxford University Press.
- Sposito G. 1984. *The Surface Chemistry of Soils*. Oxford University Press.

- Sposito G. 1989. *The Chemistry of Soils*. Oxford University Press.
- Stevenson FJ. 1994. *Humus Chemistry*. 2nd Ed. John Wiley & Sons.
- Van Olphan H. 1977. *Introduction to Clay Colloid Chemistry*. John Wiley & Sons.

I. Course Title : Soil Mineralogy, Genesis and Classification

II. Course Code : Soil 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with basic structure of alumino-silicate minerals and genesis of clay minerals; soil genesis interms of factors and processes of soil formation, and to enable students conduct soil survey and interpret soil survey reports in terms of land use planning.

V. Theory

Unit I

Fundamentals of crystallography, space lattice, coordination theory, isomorphism and polymorphism.

Unit II

Classification, structure, chemical composition and properties of clay minerals; genesis and transformation of crystal line and non-crystal line clay minerals; identification techniques; amorphous soil constituents and other non-crystalline silicate minerals and their identification; clay minerals in Indian soils, role of clay minerals in plant nutrition, interaction of clay with humus, pesticides and heavy metals.

Unit III

Factors of soil formation, soil formation models; soil forming processes; weathering of rocks and mineral transformations; soil profile; weathering sequences of minerals with special reference to Indian soils.

Unit IV

Concept of soil individual; soil classification systems – historical developments and modern systems of soil classification with special emphasis on soil taxonomy; soil classification, soil mineralogy and soil maps – usefulness.

VI. Practical

- Separation of sand, silt and clay fraction from soil
- Determination of specific surface area and CEC of clay
- Identification and quantification of minerals in soil fractions
- Morphological properties of soil profile in different land forms
- Classification of soils using soil taxonomy
- Calculation of weathering indices and its application in soil formation
- Grouping soil susing available database in terms of soil quality

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil taxonomy and genesis and and their utility in research for solving field problem.

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu. Buol EW, Hole ED, MacCracken RJ and Southard RJ. 1997. *Soil Genesis*
- *and Classification*. 4th Ed. Panima Publ.
- Dixon JB and Weed SB. 1989. *Minerals in Soil Environments*. 2nd Ed. Soil Science Society of America, Madison.
- Grim RE. 1968. *Clay Mineralogy*. McGraw Hill.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Sehgal J. 2002. *Introductory Pedology: Concepts and Applications*. New Delhi
- Sehgal J. 2002. *Pedology - Concepts and Applications*. Kalyani.
- USDA. 1999. *Soil Taxonomy*. Hand Book No. 436. 2nd Ed. USDA NRCS, Washington.
- Wade FA and Mattox RB. 1960. *Elements of Crystallography and Mineralogy*. Oxford & IBH.
- Wilding LP and Smeck NE. 1983. *Pedogenesis and Soil Taxonomy*: II. *The Soil Orders*. Elsevier.
- Wilding NE and Holl GF. (Eds.). 1983. *Pedogenesis and Soil Taxonomy*. I.

I. Course Title : Soil Erosion and Conservation

II. Course Code : Soil 505

III. Credit Hours : 2+1

IV. Aim of the course

To enable students to understand various types of soil erosion and measures to betaken for controlling soil erosion to conserve soil and water.

V. Theory

Unit I

History, distribution, identification and description of soil erosionproblems in India.

Unit II

Forms of soil erosion; effects of soil erosion and factors affecting soilerosion; types and mechanisms of water erosion; raindrops and soil erosion; rainfall erosivity - estimation as EI30 index and kinetic energy; factors affectingwater erosion; empirical and quantitative estimation of water erosion; methods of measurement and prediction of runoff; soil losses in relation to soil properties andprecipitation.

Unit III

Wind erosion- types, mechanism and factors affecting wind erosion; extent of problem in the country.

Unit IV

Principles of erosion control; erosion control measures – agronomical and engineering; erosion control structures - their design and layout.

Unit V

Soil conservation planning; land capability classification; soil conservation in special problem areas such as hilly, arid and semi-arid regions, waterlogged and wet lands.

Unit VI

Watershed management - concept, objectives and approach; water harvesting and recycling; flood control in watershed management; socioeconomic aspects of watershed management; case studies in respect to monitoring and evaluation of watersheds; use of remote sensing in assessment and planning of watersheds, sediment measurement

VI. Practical

- Determination of different soil erodibility indices - suspension percentage, dispersion ratio, erosion ratio, clay ratio, clay/moisture equivalent ratio, percolation ratio, raindrop erodibility index
- Computation of kinetic energy of falling rain drops
- Computation of rainfall erosivity index (EI30) using rain gauge data
- Land capability classification of a watershed
- Visits to a watersheds

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil conservation and their utility in research for solving field problem.

IX. Suggested Reading

- Biswas TD and Narayanasamy G. (Eds.) 1996. *Soil Management in Relation to Land Degradation and Environment*. Bull. Indian Society of Soil Science No. 17.
- Doran JW and Jones AJ. 1996. *Methods of Assessing Soil Quality*. Soil Science Society of America, Spl Publ. No. 49, Madison, USA.
- Gurmal Singh, Venkataramanan C, Sastry G and Joshi BP. 1990. *Manual of Soil and Water Conservation Practices*. Oxford & IBH.
- Hudson N. 1995. *Soil Conservation*. Iowa State University Press.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. Course Title : Soil Biology and Biochemistry

II. Course Code : Soil 506

III. Credit Hours : 2+1

IV. Aim of the course

To teach students the basics of soil biology and biochemistry, including biogeochemical cycles, plant growth promoting rhizobacteria, microbial interactions in soil and other soil activities.

V. Theory

Unit I

Soilbiota, soil microbialecology, types of organisms indifferent soils; soil microbial biomass; microbial interactions; un-culturable soilbiota.

Unit II

Microbiology and biochemistry of root-soil interface; phyllosphere; soil enzymes, origin, activities and importance; soil characteristics influencing growth and activity of microflora; Root rhizosphere and PGPR.

Unit III

Microbial transformations of nitrogen, phosphorus, sulphur, iron and manganese in soil; biochemical composition and biodegradation of soil organic matter and crop residues, microbiology and biochemistry of decomposition of carbonaceous and protenaceous materials, cycles of important organic nutrients.

Unit IV

organic wastes and their use for production of biogas and manures; biotic factors in soil development; microbial toxins in the soil.

Unit V

Preparation and preservation of farmyard manure, animal manures, rural and urban composts and vermicompost.

Unit VI

Biofertilizers–definition, classification, specifications, method of production and role in crop production; FCO specifications and quality control of biofertilizers.

Unit VII

Biological indicators of soil quality; bioremediation of contaminated soils; microbial transformations of heavy metals in soil; role of soil organisms inpedogenesis – important mechanisms and controlling factors; soil genomics and bioprospecting; soil sickness due to biological agents; xenobiotics; antibiotic production in soil.

VI. Practical

- Determination of soil microbial population
- Soil microbial biomass carbon
- Elemental composition, fractionation of organic matter and functional groups
- Decomposition of organic matter in soil
- Soil enzymes
- Measurement of important soil microbial processes such as ammonification, nitrification, N_2 fixation, S oxidation, P solubilization and mineralization of other micronutrients

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil microbes and their utility in research for solving field problem.

IX. Suggested Reading

- Paul EA and Clark FE. *Soil Microbiology and Biochemistry.*
- Lynch JM. *Soil Biotechnology*
- Willey JM, Linda M. Sherwood and Woolverton CJ. *Prescott's Microbiology.*
- Subba Rao NS. *Advances In Agricultural Microbiology.*

I. Course Title : Radioisotopes in Soil and Plant Studies

II. Course Code : Soil 507

III. Credit Hours : 1+1

IV. Aim of the course

To train students in the use of radio isotopes in soil and plant research.

V. Theory

Unit I

Atomic structure, radio activity and units; radio isotopes-properties and decay principles; nature and properties of nuclear radiations; interaction of nuclear radiations with matter, artificial radioactivity

Unit II

Principles and use of radiation monitoring instruments-proportional, Geiger Muller counter, solid and liquids cintillation counters; neutron moisture meter, mass spectrometry, autoradiography

Unit III

Isotopic dilution techniques used in soil and plant research; use of stable isotopes; application of isotopes in studies on organic matter, nutrient transformations, ion transport, rooting pattern and fertilizer use efficiency; carbon dating

Unit IV

Doses of radiation exposure, radiation safety aspects regulatory aspects, collection, storage and disposal of radioactive wastes

VI. Practical

- Storage and handling of radioactive materials
- Determination of half-life and decay constant
- Preparation of soil and plant samples for radioactive measurements
- Settingup of experiment on fertilizer use efficiency and cation exchange equilibria using radio isotopes
- Determination of A, E and L values of soil using 32P/65Zn
- Use of neutron probe for moisture determination
- Sample preparation and measurement of 15N enrichment by mass spectro photometery/ emission spectrometry

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of radio activity and their utility in research for solving field problems.

IX. Suggested Reading

- Comer CL. 1955. *Radioisotopes in Biology and Agriculture: Principles and Practice*. Tata McGraw Hill.
- Glasstone S. 1967. *Source Book on Atomic Energy*. East West Press.
- Michael FL and Annunziata. 2003. *Handbook of Radioactivity Analysis*. Academic Press.

I. Course Title : Soil, Water and Air Pollution

II. Course Code : Soil 508

III. Credit Hours : 2+1

IV. Aim of the course

To make the student saw are of the problems of soil, water and air pollution associated with use of soils for crop production.

V. Theory

Unit I

Soil, water and air pollution problems associated with agriculture, nature and extent.

Unit II

Nature and sources of pollutants – agricultural, industrial, urban wastes, fertilizers and pesticides, acid rains, oil spills etc.; air, water and soil pollutants- their CPC standards and effect on plants, animals and human beings.

Unit III

Sewage and industrial effluents–their composition and effecton soil properties/ health, and plant growth and humanbeings; soil as sink for waste disposal.

Unit IV

Pesticides–their classification, behaviour in soil and effecton soil microorganisms.

Unit V

Toxic elements–their sources, behaviour in soils, effect on nutrients availability, effect on plant and human health.

Unit VI

Pollution of water resources due to leaching of nutrients and pesticides from soil; emission of green house gases–carbondioxide, methane and nitrous oxide.

Unit VII

Risk assessment of polluted soil, Remediation/ amelioration of contaminated soil and water; remote sensing applications in monitoring and management of soil and water pollution.

VI. Practical

Sampling of sewage waters, sewage sludge, solid/ liquid industrial wastes, polluted soils and plants and their processing, Estimation of dissolved and suspended solids, chemical oxygen demand (COD), biological demand (BOD), measurement of coliform (MPN), nitrate and ammoniacal nitrogen and phosphorus, heavy metal content in effluents, Heavy metals in contaminated soils and plants, Management of contaminants in soil and plants to safe guard food safety, Air sampling and determination of particulate matter and oxides of sulphur, NO_2 and O_2 conc**.** Visit to various industrial sites to study the impact of pollutants on soil and plants.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Management of soil and water pollution

IX. Suggested Reading

- Lal R, Kimble J, Levine E and Stewart BA. 1995. *Soil Management and Greenhouse Effect*. CRC Press.
- Middlebrooks EJ. 1979. *Industrial Pollution Control*. Vol. I. *Agro-Industries*. John Wiley Interscience.
- Ross SM. *Toxic Metals in Soil Plant Systems*. John Wiley & Sons.
- Vesilund PA and Pierce 1983. *Environmental Pollution and Control*. Ann Arbor Science Publ.

I. Course Title : **Remote Sensing and GIS Technique for Soil, Water and Crop Studies**

II. Course Code : **Soil 509**

III. Credit Hours : **2+1**

IV. Aim of the course

To impart knowledge about the basic concepts of remote sensing, aerial photographs and imageries, and their interpretation; application of remote sensing in general and with special reference to soil, plants and yield forecasting; to impart knowledge about geo-statistical techniques with special reference to krigging, and GIS and applications in agriculture.

V. Theory

Unit I

Introduction and history of remote sensing; sources, propagation of radiations in atmosphere; interactions with matter, basic concepts and principles; hardware and software requirements; common terminologies of geographic information system (GIS)

Unit II

Sensor systems-camera, microwave radio meters and scanners; fundamentals of aerial photographs and multispectral imaging, hyperspectral imaging, thermal imaging; image processing and interpretations.

Unit III

Application of remote sensing techniques-landuse soil surveys, crop stress and yield forecasting, prioritization in watershed and drought management, waste land identification and management.

Unit IV

Significance and sources of the spatial and temporal variability in soils; variability in relation to size of sampling; classical and geo-statistical techniques of evolution of soil variability.

Unit V

Applications of GIS for water resources, agriculture, precision farming, disaster management, e-governance, Agricultural Research Information System (ARIS).

VI. Practical

Familiarization with different remote sensing equipments and data products, Interpretation of aerial photo graphs and satellite data for mapping of land resources, Analysis of variability of different soil properties with classical and geostatistical techniques, Creation of datafiles in a database programme, Use of GIS for soil spatial simulation and analysis, To enable the students to conduct soil survey and interpret soil survey reports in terms of land use planning.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and their utility in research for solving field problem.

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- Elangovan K. 2006. *GIS Fundamentals, Applications and Implementations*. New India Publ. Agency.
- Lillesand TM and Kiefer RW. 1994. *Remote Sensing and Image Interpretation*. 3rd Ed. Wiley.
- Nielsen DR and Wendroth O. 2003. *Spatial and Temporal Statis*tics. Catena Verloggmbh.
- Star J and Esles J. 1990. *Geographic Information System: An Introduction*. Prentice Hall.

I. Course Title : Analytical Technique and Instrumental Methods in Soil and Plant Analysis

II. Course Code : Soil 510

III. Credit Hours : 0+2

IV. Aim of the course

To familiarize the students with commonly used instruments – their working, preparations of common analytical reagents for qualitative and quantitative analysis of both soil as well as plant samples.

V. Practical

Unit I

Preparation of solutions for standard curves, indicators and standard solutions for acid-base, oxidation reduction and complexometric titration; soil, water and plant sampling techniques, their processing and handling.

Unit II

Determination of nutrient potentials and potential buffering capacities of soils for phosphorus and potassium; estimation of phosphorus, ammonium and potassium fixation capacities of soils.

Unit III

Principles of visible, ultra violet and infrared spectrophotometery, atomic absorption, flame-photometry, inductively coupled plasma spectrometry; chromatographic techniques, mass spectrometry and X-ray defractrometery; identification of minerals by X-ray by different methods, CHNS analyzer.

Unit IV

Electrochemical titration of clays; estimation of exchangeable cations (Na, Ca, Mg, K); estimation of root cation exchange capacity.

Unit V

Wet digestion/fusion/extraction of soil with aquaregia with soil for elemental analysis; triacid/di-acid digestion of plant samples; determination of available and total nutrients (N, P, K, S, Ca, Mg, Zn, Cu, Fe, Mn, B, Mo) in soils; determination of total nutrients (N, P, K, S, Ca, Mg, Zn, Cu, Fe, Mn, B, Mo) in plants

Unit VI

Drawing normalized exchange isotherms; measurement of redox potential.

VI. Teaching methods/activities

Classroom teaching and laboratory practicals

VII. Learning outcome

Development of confidence for setting soil testing laboratory.

VIII. Suggested Reading

- Hesse P. 971. *Textbook of Soil Chemical Analysis*. William Clowes & Sons.
- Jackson ML. 1967. *Soil Chemical Analysis*. Prentice Hall of India.
- Keith A Smith 1991. *Soil Analysis; Modern Instrumental Techniques*. Marcel Dekker.
- Kenneth Helrich 1990. *Official Methods of Analysis*. Association of Official Analytical Chemists.
- Page AL, Miller RH and Keeney DR. 1982. *Methods of Soil Analysis*. Part II. SSSA, Madison.
- Piper CE. *Soil and Plant Analysis*. Hans Publ.
- Singh D, Chhonkar PK and Pandey RN. 1999. *Soil Plant Water Analysis - A Methods Manual*. IARI, New Delhi.
- Tan KH. 2003. *Soil Sampling, Preparation and Analysis*. CRC Press/Taylor & Francis.
- Tandon HLS. 1993. *Methods of Analysis of Soils, Fertilizers and Wat*ers. FDCO, New Delhi.
- Vogel AL. 1979. *A Textbook of Quantitative Inorganic Analysis*. ELBS Longman.

I. Course Title : Management of Problem Soils and Water

II. Course Code : Soil 511

III. Credit Hours : 2+1

IV. Aim of the course

To educate students about basic concepts of problem soils and brackish water, and their management. Attention will be on management of problem soils and safe use of brackish water in relation to crop production.

V. Theory

Unit I

Area and distribution of problem soils–acidic, saline, sodic and physically degraded soils; origin and basic concept of problematic soils, and factors responsible.

Unit II

Morphological features of saline, sodic and saline-sodic soils; characterization of salt-affected soils-soluble salts, ESP, pH; physical, chemical and microbiological properties.

Unit III

Management of salt-affected soils; salt tolerance of crops- mechanism and ratings; salt stress meaning and its effect on crop growth, monitoring of soils alinity in the field; management principles for sandy, clayey, red lateritic and dryland soils.

Unit IV

Acid soils-nature of soil acidity, sources of soil acidity; effect on plant growth, lime requirement of acid soils; management of acid soils; biological sickness of soils and its management.

Unit V

Quality of irrigation water; management of brackish water for irrigation; salt balance under irrigation; characterization of brackish waters, area and extent; relationship in water use and quality.

Unit VI

Agronomic practices in relation to problematic soils; cropping pattern for utilizing poor quality groundwaters.

VI. Practical

Characterization of acid, acid sulfate, salt-affected and calcareous soils, Determination of cations (Na+, K+, Ca++ and Mg++) in groundwater and soil samples, Determination of an ions (Cl^-, SO_4^-, CO_3^- and HCO_{3-}) in ground waters and soil samples, Lime and gypsum requirements of acid and sodic soils.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on solving field problem of problem soil and waters.

IX. Resources

- Bear FE. 1964. *Chemistry of the Soil*. Oxford & IBH.
- Jurinak JJ. 1978. *Salt-affected Soils*. Department of Soil Science & Biometeorology. Utah State University
- USDA Handbook No. 60. 1954. *Diagnosis and improvement of Saline and Alkali Soils*. Oxford & IBH.

I. Course Title : Land Degradation and Restoration

II. Course Code : Soil 512

III. Credit Hours : 1+0

IV. Aim of the course

To impart knowledge related to various factors and processes of land degradation and their restoration techniques.

V. Theory

Unit I

Type, factors and processes of soil/land degradation and its impact on soil productivity including soil fauna, biodegradation and environment.

Unit II

Land restoration and conservation techniques-erosion control, reclamation of salt-affectedsoils; minelandreclamation, afforestation, organic products.

Unit III

Extent, diagnosis and mapping of land degradation by conventional and modern RS-GIS tools; monitoring land degradation by fast assessment, modern tools, land use policy, incentives and participatory approach for reversing land degradation; global issues for twenty first century.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on restoration of degraded soil for optimization of crop yield.

VIII. Suggested Reading

- Biswas TD and Narayanasamy G. (Eds.). 1996. *Soil Management in Relation to Land Degradation and Environment*. Bull. Indian Soc. Soil Sci. 17, New Delhi.
- Doran JW and Jones AJ. 1996. *Methods of Assessing Soil Quality*. Soil Science Society of America, Madison.
- Greenland DJ and Szabolcs I. 1994. *Soil Resilience and Sustainable Land Use*. CABI.
- Lal R, Blum WEH, Vailentine C and Stewart BA. 1997. *Methods for Assessment of Soil Degradation*. CRC Press.
- Sehgal J and Abrol IP. 1994. *Soil Degradation in India - Status and Impact*. Oxford & IBH.

I. Course Title : Soil Survey and Land Use Planning

II. Course Code : Soil 513

III. Credit Hours : 2+0

IV. Aim of the course

To teach the better utilization of land for agricultural purposes, and better management of run-off or surplus/ excessive rain-water in the catchment area for agricultural purposes in a watershed.

V. Theory

Unit I

Soil survey and its types; soil survey techniques- conventional and modern; soil series–characterization and procedure for establishing soil series; benchmark soils and soil correlations; soil survey interpretations; thematic soil maps, cartography, mapping units, techniques for gene ration of soil maps, application of remote sensing and GIS in soil survey and mapping of major soil group of India

Unit II

Landform–soil relationship; major soil groups of India with special reference to respective states; land capability classification and land irrigability classification; land evaluation and land use type (LUT)–concept and application; approaches for managing soils and landscapes in the framework of agro-ecosystem.

Unit III

Concept and techniques of land use planning; factors governing present land use; Land evaluation method sand soil-site suitability evaluation for different crops; land capability classification and constraints in application.

Unit IV

Agro-ecological regions/sub-regions of India and their characteristics in relation to crop production. Status of LUP in India.

VI. Practical

- Aerial photo and satellite data interpretation for soil and land use
- Cartographic techniques for preparation of base maps and thematic maps, processing of field sheets, compilation and obstruction of maps in differentscales
- Land use planning exercises using conventional and RS tools

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field visit and exposure visit

VIII. Learning outcome

Planning for land use in proper way for higher crop productivity.

IX. Suggested Reading

- Boul SW, Hole ED, MacCraken RJ and Southard RJ. 1997. *Soil Genesis and Classification*. 4th Ed. Panima Publ.
- Brewer R. 1976. *Fabric and Mineral Analysis of Soils*. John Wiley & Sons.

I. Course Title : Introduction to Nanotechnology

II. Course Code : Soil 514

III. Credit Hours : 2+1

IV. Aim of the course

To impart basic knowledge about nanoscience, properties of nanoparticles and their applications in biology

V. Theory

Unit I

General introduction: Basics of quantum mechanics, harmonic oscillator, magnetic phenomena, band structure in solids, Mössbauer effect and spectroscopy, optical phenomena, bond in solids, an isotropy.

Unit II

Nanostructures: growth of compound semiconductors, super lattices, self-assembled quantum dots, nano-particles, nano tubes and nanowires, fullerenes (buckballs, graphene). Nanofabrication and nano-patterning: Optical, X-ray, and electron beam lithography, self-assembled organic layers, process of synthesis of nanopowders, electrode position, important nanomaterials.

Unit III

Mechanical properties, magnetic properties, electrical properties, electronic conduction with nanoparticles, investigating and manipulating materials in the nanoscale: Electron microscopy

Unit IV

Nano-biology: Interaction between biomolecules and nano-particle surface, different types of in organic materials used for the synthesis of hybrid nano-bioassemblies, application of nano-inagriculture, current status of nano-biotechnology, future perspectives of nano-biology, nano-sensors.

VI. Practical

- Sources of nanoparticles and its preparation by different approaches
- Electrospinning and its use in agriculture and allied sector.
- Equipments used in Nanotechnology: its principle and uses
- Acquaintances with different equipments used in nanotechnology.
- Synthesis and characterization of Ag and ZnO nanoparticles.
- Mode of action of ZnO nanoparticles against soil borne diseases
- Study on efficacy of ZnO nanoparticles as seed treating agent on plant growth parameters.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of nano science and their utility in research for solving field problem.

IX. Suggested Reading

- Balandin AA and Wang KL. 2006. *Handbook of semiconductor nano structures and nano devices.* California: American Scientific Publishers.
- Timp G. 1999. *Nanotechnology*. New York: Springer Verlag.
- Challa Kumar SSR. 2006. *Nanotechnologies for the life sciences.* Weinheim: Wiley-VCHGmbH.
- Kohler M and Frintzsche W. 2007. *Nanotechnology: Introduction to nanostructuring techniques* W Weinheim: Wiley-VCH Verlag GmbH.
- Kosal ME. 2009. *Nanotechnology for chemicao and biological defense*. Dordrecht: Stringer.

Course Title with Credit Load
Ph.D. in Soil Science

Course Code	Course Title	Credit Hours
Soil 601	Recent trends in soil physics	2+0
Soil 602	Modern concept in soil fertility	2+0
Soil 603*	Physical chemistry of soil	2+0
Soil 604*	Soil genesis and micromorphology	2+0
Soil 605	Bio-chemistry of soil organic matter	2+0
Soil 606	Soil resource management	3+0
Soil 607	Modelling of soil plant system	2+0
Soil 608	Clay Mineralogy	2+1
Soil 609	Recent trends in soil microbial biodiversity	2+1
Soil 691	Doctoral seminar	1+0
Soil 692	Doctoral seminar	1+0
Soil 699	Doctoral Research	-75

*Indicates Core Courses which are Compulsory for PhD Programme

Course Contents
Ph.D. in Soil Science

I. Course Title : Recent Trends in Soil Physics
II. Course Code : Soil 601
III. Credit Hours : 2+0

IV. Aim of the course

To provide knowledge of modern concept sin soil physics.

V. Theory

Unit I

Soil-water interactions, soil water potential, free energy and thermodynamic basis of potential concept, chemical potential of soil water and entropy of the system, soil-plant-atmospheric continuum (SPAC).

Unit II

Fundamentals of fluid flow, Poiseuilles law, Laplace's equation, Darcy's law in saturated and unsaturated flows; development of differential equations in saturated and unsaturated waterflow, capillary conductivity and diffusivity; limitations of Darcy's law; numerical solution for one dimensional waterflow.

Unit III

Theories of horizontal and vertical infiltration under different boundary conditions.

Unit IV

Movement of salts in soils, models formiscible-immiscible displacement, diffusion, mass flow and dispersion of solutes and their solutions through differential equations; break-through curves.

Unit V

Soil air and aeration, mass flow and diffusion processes; thermal properties of soil, heat transfer in soils, differential equation of heatflow, measurement of thermal conductivity of soil; Soil, Plant, Water relations- Plant uptake of soil moisture, Water balance and energy balance in the field; irrigation and water use efficiency.

Unit VI

Soil crust and clod formation; structural management of puddled rice soils; soil conditioning-concept, soils conditioners-types, characteristics, working principles, significance in agriculture.

Unit VII

Solar and terrestrial radiation measurement, dissipation and distribution in soil-crop systems; prediction of evapotranspiration using aerodynamic and canopy temperature-based models; canopy temperature and leaf diffusion resistance in relation to plant water deficit; evaluation of soil and plant water status using infra-red thermometer.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

VIII. Suggested Reading

- Baver LD, Gardner WH and Gardner WR. 1972. *Soil Physics*. John Wiley & Sons.
- Hanks and Ascheroft. 1980. *Applied Soil Physics*. Springer Verlag.
- Hillel D. 1980. *Applications of Soil Physics*. Academic Press.
- Hillel D. 1980. *Environmental Soil Physic*s. Academic Press.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Kirkham D and Powers WL. 1972. *Advanced Soil Physics*. Wiley Interscience.
- Lal R and Shukla MK. 2004. *Principles of Soil Physics*. Marcel Dekker.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. Course Title : Modern Concept in Soil Fertility

II. Course Code : Soil 602

III. Credit Hours : 2+0

IV. Aim of the course

To provide knowledge of modern concepts of soil fertility and nutrient use in crop production.

V. Theory

Unit I

Nutrient availability-concept and relationships, modern concepts of nutrient s availability; soil colloids and nutrient availability; soil amendments and availability maintenance of nutrients, soil solution and plant growth; nutrient response functions and availability indices.

Unit II

Nutrient movement in soils; nutrient absorption by plants; mechanistic approach to nutrient supply and uptake by plants; models for transformation and movement of major micronutrients in soils.

Unit III

Chemical equilibria (including solid-solution equilbria) involving nutrientions in soils, particularly in submerged soils; Kinetic studies of nutrients in soils.

Unit IV

Modern concepts of fertilizer evaluation, nutrient use efficiency and nutrient budgeting.

Unit V

Modernconcepts in fertilizer application; soil fertility evaluation techniques; role of soil tests in fertilizer use recommendations; site-specific nutrient management for precision agriculture.

Unit VI

Monitoring physical, chemical and biological changes in soils; permanent manurial trials and long-term fertilizer experiments; soil productivity under long-term intensive cropping; direct, residual and cumulative effect of fertilizer use.

Unit VII

Carbon– a nutrient central to soil fertility; carbon cycle in nature, stocks, pools and fluxes; greenhouse effect and climate change; carbon sequestration vis-à-vis sustenance of soil quality and crop productivity.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil fertility and fertilizers in relation to plant growth and development.

VIII. Suggested Reading

- Barber SA. 1995. *Soil Nutrient Bioavailability*. John Wiley & Sons.
- Barker V Allen and Pilbeam David J. 2007. *Handbook of Plant Nutrition*. CRC / Taylor & Francis.
- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Educ.
- Cooke GW. 1979. *The Control of Soil Fertility*. Crossby Lockwood & Sons.
- Epstein E. 1987. *Mineral Nutrition of Plants - Principles and Perspectives*. International Potash Institute, Switzerland.
- Kabata- Pendias Alina 2001. *Trace Elements in Soils and Plants*. CRC / Taylor & Francis.
- Kannaiyan S, Kumar K and Govindarajan K. 2004. *Biofertilizers Technolo*gy. Scientific Publ.
- Mortvedt JJ, Shuman LM, Cox FR and Welch RM. (Eds.). 1991. *Micronutrients in Agriculture.* 2nd Ed. Soil Science Society of America, Madison.
- Prasad R and Power JF. 1997. *Soil Fertility Management for Sustainable Agriculture*. CRC Press.
- Stevenson FJ and Cole MA. 1999. *Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulphur, Micronutrients*. John Wiley & Sons.
- Stevenson FJ. (Ed.). 1982. *Nitrogen in Agricultural Soils*. Soil Science Society of America, Madison.
- Tisdale SL, Nelson WL, Beaton JD and Havlin JL. 1990. *Soil Fertility and Fertilizers*. 5th Ed. Macmillan Publ.
- Wild A. (Ed.). 1988. *Russell's Soil Conditions and Plant Growth*. 11th Ed. Longman.

I. Course Title : Physical Chemistry of Soil

II. Course Code : Soil 603

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge about modern concepts of physical chemistry of soils and clays, with emphasis on understanding the processes involved with practical significance.

V. Theory

Unit I

Colloidal chemistry of in organic and organic components of soils–their formation, clay organic interaction.

Unit II

Predictive approaches for cation exchange equilibria- thermodynamics, empirical and diffuse double layer theory (DDL)- relationships among different selectivity coefficients; structure and properties of diffuse double layer.

Unit III

Thermodynamics of nutrient transformations in soils; Climate change effects on minerology and surface properties of variable charge; cationic and anionic exchange and their models, molecular interaction.

Unit IV

Adsorption/desorption isotherms-Langmuir adsorption isotherm, Freundlich adsorption isotherm, normalized exchange isotherm, BET equation; selective and non-selective adsorption of ions on in organic surfaces and organic surfaces of soil materials (citation of utility in agricultural system).

Unit V

Common solubility equilibria-carbonates, ironoxide and hydroxides, aluminum silicate, aluminum phosphate; electrochemical properties of clays (citation of examples from agricultural use).

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil chemical behaviour on research for solving field problems.

VIII. Suggested Reading

- Bear RE. 1964. *Chemistry of the Soil*. Oxford & IBH.
- Bolt GH and Bruggenwert MGM. 1978. *Soil Chemistry*. Elsevier.
- Fried M and Broeshart H. 1967. *Soil Plant System in Relation to Inorganic Nutrition*. Academic Press.
- Greenland DJ and Hayes MHB. 1981. *Chemistry of Soil Processes*. John Wiley & Sons.
- Greenland DJ and Hayes MHB. 1978. *Chemistry of Soil Constituents*. John Wiley & Sons.
- Jurinak JJ. 1978. *Chemistry of Aquatic Systems*. Department of Soil Science and Biometeorology, Utah State University
- McBride MB. 1994. *Environmental Chemistry of Soils*. Oxford University Press.
- Sparks DL. 1999. *Soil Physical Chemistry*. 2nd Ed. CRC Press.
- Sposito G. 1981. *The Thermodynamics of Soil Solutions*. Oxford University Press.
- Sposito G. 1984. *The Surface Chemistry of Soils*. Oxford University Press.
- Sposito G. 1989. *The Chemistry of Soils*. Oxford University Press.
- Stevenson FJ. 1994. *Humus Chemistry*. 2nd Ed. John Wiley.
- van Olphan H. 1977. *Introduction to Clay Colloid Chemistry*. John Wiley & Sons.

I. Course Title : Soil Genesis and Micromorphology

II. Course Code : Soil 604

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge about the pedogenic processes in soils and to acquaint with the micro-pedological study of soil profile.

V. Theory

Unit I

Pedogenic evolution of soils; soil composition and characterization.

Unit II

Weathering and soil formation–factors and pedogenic processes; stability and weathering sequences of minerals.

Unit III

Assessment of soil profile development by mineralogical and chemical analysis.

Unit IV

Micro-pedological features of soils–their structure, fabric analysis, role in genesis and classification.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil micro pedology and soil taxonomy on research for solving field problems.

VIII. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- Buol EW, Hole ED, MacCracken RJ & Southard RJ. 1997. *Soil Genesis and Classification*. 4th Ed. Panima Publ.
- Dixon JB and Weed SB. 1989. *Minerals in Soil Environments*. 2nd Ed. Soil Science Society of America, Madison.
- Grim RE. 1968. *Clay Mineralogy*. McGraw Hill.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Sehgal J. 2002. *Introductory Pedology: Concepts and Applications*. New Delhi
- Sehgal J. 2002. *Pedology - Concepts and Applications*. Kalyani.
- USDA. 1999. *Soil Taxonomy*. Hand Book No. 436. 2nd Ed. USDA NRCS, Washington.
- Wade FA and Mattox RB. 1960. *Elements of Crystallography and Mineralogy*. Oxford & IBH.

I. Course Title : Biochemistry of Soil Organic Matter

II. Course Code : Soil 605

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge related to chemistry and reactions of organic substances and their significance in soils.

V. Theory

Unit I

Organic matter in soils and its maintenance Role of organic matter in soil productivity; humus levels in soils; current thinking on the maintenance of organic matter in the soils. Carbon retention and sequestration.

Unit II

Biochemistry of the humus formation; different pathways for humus synthesis in soil; soil carbohydrates and lipids.

Unit III

Nutrient transformation–N, P, S; tracemetal interaction with humic substances, significance of chelation reactions in soils.

Unit IV

Reactive functional groups of humic substances, adsorption of organic compounds by clay and role of organic substances in pedogenic soil aggregation processes; clay-organic matter complexes.

Unit V

Humus-pesticide interactions in soil, mechanisms.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil biochemistry on research for solving field problems.

VIII. Reading Materials

- Lynch JM, Willey JM. *Soil Biotechnology*.
- Paul EA and Clark FE. *Soil Microbiology and Biochemistry*
- Sherwood LM and Woolverton CJ. *Prescott's Microbiology*.
- Subba Rao NS. *Advances In Agricultural Microbiology*

I. Course Title : Soil Resource Management

II. Course Code : Soil 606

III. Credit Hours : 3+0

IV. Aim of the course

To impart the students basic holistic knowledge on soil resource and latest developments in its sustainable use.

Unit I

Relevance of soil management to sustainable agriculture; soil as a natural resource for biomass production, filtering, buffering, transportation of solutes, genereserves, and geogenic source of raw materials; soil as a source and sink of greenhouse gases.

Unit II

Concept of sustainable land management (SLM); spatial variability of soils; soil quality and food security; soil quality indices, conservation agriculture in relation to soil quality; soil resilience and resistance.

Unit III

Types, factors and causes of land degradation and desertification; GLASOD classification; application of GIS and remote sensing in monitoring, diagnosis and mapping land degradation; history, distribution, identification and description of soil erosion problems in India; forms of soil erosion; impact of soil erosion-on-site and off-site effects; strategies for erosion control and conservation; soil conservation in hilly, arid, semiarid, coastal and diaralands. Management of forest, peat and muck soils.

Unit IV

Soil conservation planning; land capability classification; soil conservation in special problem are as such as hilly, arid and semi-arid regions, waterlogged and wetlands; land restoration and conservation techniques–erosion control, reclamation of salt affected soils; mine land reclamation, afforestation, organic products, soil fauna and biodegradation.

Unit V

Watershed management-concept, objectives and approach; water harvesting and recycling; flood control in watershed management; socio-economic aspects of watershed management; case studies in respect to monitoring and evaluation of watersheds.

Unit VI

Agro-ecological regions of India; potentials and constraints of soils of different regions; land evaluation and rationalizing land use, decision support system with relation to land management; national and international soil policy considerations.

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VI. Learning outcome

Experience on the knowledge of soil resources on research for solving field problems.

VII. Suggested Reading

- Abrol IP and Dhruvanarayana VV. 1990. *Technology for Wasteland Development*. ICAR, New Delhi.
- Andriesse JP. 1988. *Nature and Management of Tropical Peat Soils*, Soil Resources, FAO Soils Bulletin 59, Management and Conservation Service, Land and Water Development Division, FAO, Rome
- Blackwell, Dent D and Young A. 1981. *Soil Survey and Land Evaluation*. George Allen and Unwin, London.
- Burrough A and McDonnell RK. 1998.*Principles of Geographical Information System*. Oxford University Press.
- Dan Binkley D and Fisher R. 2012. *Ecology and Management of Forest Soils*,4th Edition, Wiley.
- FAO. 1996. *Land Quality Indicators and their Use in Sustainable Agriculture and Rural Development*. FAO Land and Water Bulletin.5. FAO, Rome.
- Faroq M and Siddique K. (Ed.). 2015. *Conservation Agriculture*, Springer Nature, Chennai, India.
- FESL. 1993. *An International Framework for Evaluating Sustainable Land Management, FAO World Soil Resources Report No. 73*, Land Development Division, FAO, Rome.
- ISSS. 1994. *Management of Land and Water Resources for Sustainable Agriculture and Environment*. Diamond Jubilee Symposium Publication, Indian Society of Soil Science, New Delhi.
- Lal R, Blum WEH, Valentine C and Stewart BA. (Editors). 1988. *Methods for Assessment of Soil Degradation*. CRC Press, Boca Raton.
- Mulders MA. 1987. *Remote Sensing in Soil Science*. Elsevier Science Publishers, Amsterdam.
- Sehgal J. 2014. *A Text Book of Pedology Concepts and Application*. Kalyani publishers, New Delhi.
- SSSA 1996. *Methods for Assessing Soil Quality*. SSSA Publication Number 49, Madison, Wisconsin, USA.

I. Course Title : Modelling of Soil Plant System

II. Course Code : Soil 607

III. Credit Hours : 2+0

IV. Aim of the course

To train the students in concepts, methodology, technology and use of systems simulation in soil and crop studies

V. Theory

Unit I

Introduction, terms and definitions; classification of models; Taylor series; numerical methods of differentiation and integration.

Unit II

High level computer language: FORTRAN-its commands and usage; testing and evaluation of model.

Unit III

Description of spatially homogeneous models; K transformation model; nitrogen and phosphorus dynamics in soil.

Unit IV

Spatially heterogeneous models; equation of continuity; Simulation of water flow through soil; Explicit and Explicit-Implicit method; simulation of solute movement through soil with variable moisture flux by explicit-implicit method.

Unit V

Nutrient uptake model: Integration of nutrient movement in soil (mass flow and diffusion) and uptake by plants (Michaelis-Menten kinetics); Nutrient uptake model: Solubility and free ion activity model.

IV. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on soil modelling concept for forecasting productivity

VIII. Suggested Reading

- Datta SC. 2008. *Theory and Principles of Simulation Modeling in Soil-Plant System*. Capital Publishing Company, New Delhi.
- Frame J and Thornley JHM. 1984. *Mathematical Models in Agriculture—A Quantitative approach to problems in agriculture and related science*. Butterworth and Co. Ltd.
- Freud PJ and Minton PD. 1979. *Regression Methods—A tool for data Analysis*. Marcel Dekker Inc., New York.
- Frissel MJ and Reinger P. 1974. *Simulation of Accumulation and Leaching in Sils*. Oxford and IBM Pub. Co., New Delhi.
- Hanks J and Richie JT. (Eds.). 1991. *Modeling Plant and Soil System*. Agronomy Bulletin No. 31, ASA, SSSA Madison, Wisconsin, USA.
- Lipschutz S and Poe A. 1978. *Schaum's Outline Series–Theory and Problems of programming with Fortran*. McGraw-Hill Book Co., Singapore.
- Penning de Vries FWT, Jansen DM, Ten Berge HFM and Baker A. 1989. *Simulation of ecophysiological processes of growth in several annual crops*. PUDOC, Wageningen.
- Shaffer MJ, Ma L and Hansen S. 2001. *Modeling Carbon and Nitrogen Dynamics for Soil Management*. Lewis Publishers, Boca Raton.

I. Course Title : Clay Mineralogy
II. Course Code : Soil 608
III. Credit Hours : 2+1

IV. Theory

Unit I

Definition and concepts of clays and clay minerals, Fundamentals of crystallography – unit cell, external characteristics of crystals, crystallographic notations, crystal systems.

Unit II

Structures and classification of silicate minerals, basics of phyllosilicates, laws governing structural characteristics of phyllosilicates, Goldschmitdt's laws – Laws I and Law II, Classification of Phyllosilicates.

Unit III

Kaolonite group of minerals, Dioctahedral kaolins and Trioctahedral kaolins.

Unit IV

Smectites; properties of smectites, Reference models of structure, principal types based on Hofmann-Marshal-Hendricks (H-M-H) models, occurrence of smectites, transformation and formation in soils.

Unit V

Micas: occurrence and origin in soils, polytypes of micas, structure and formation of muscovites and illite.

Unit VI

Vermicullites: structure, occurrence in soils, formation, relation between vermiculites and montmorillonite.

Unit VII

Chlorite: occurrence and structure of chlorites, "swelling chlorites", formation of chlorite.

Unit VIII

Non-crystalline clays (amorphous materials), subgroups and chemical composition, morphology and structure, physico-chemical properties, influence of non-crystalline clays on soil properties.

Unit IX

Interstratified clay minerals, occurrence and formation in soils, regularly interstratified and partially random interstratified minerals.

Unit X

Genesis and transformation of clay minerals, Generalized conditions for formation and persistence of common clay-size minerals in soils.

Unit XI

Surface chemistry of clay minerals, clay-organic complexes, nanoclay mineralogy.

Unit XII

Clay minerals in different soil orders, role of clay minerals in soil fertility management.

V. Practicals

- Separation of clay for mineralogical study
- X-ray diffraction analysis of clay
- Selective dissolution of clay minerals
- IR, DTA and SEM of clay minerals
- Identification and quantification of clay minerals
- Determination of surface charge of clay minerals
- Potentiometric titration of clay minerals.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on soil clays and utility in soil research.

VIII. Suggested Reading

- Dixon JB and Weed SB (Co-editors). *Minerals in Soil Environment.*
- Gieseking JE (Ed). *Soil Component*, Vol. 2. Inorganic Components.
- Grim RE. *Clay Mineralogy*.
- Mukherjee SK and Biswas TD (Editors). *Mineralogy of Soil Clays and Clay Minerals.*
- Read HH. *Rutley's Elements of Mineralogy.*
- Wilding LP and Smeck NE. 1983. *Pedogenesis and Soil Taxonomy Part II – Soil Orders.*

I. Course Title : Recent Trends in Soil Microbial Biodiversity

II. Course Code : Soil 609

III. Credit Hours : 2+1

IV. Theory

Unit I

Microbial evaluation and biodiversity, Microbial communities in ecosystems, New insights in below ground diverse of plant performance.

Unit II

Qualitative ecology of microorganisms; Biomass and activities.

Unit III

Nitrogen fixing organisms, Trends in diversity of N fixing organisms. Molecular approaches in characterising N fixing microorganisms.

Unit IV

Serology and molecular characterization, ecological aspects of bio determination, soil waste and water management

Unit V

Biodegradability, testing and monitoring of the bioremediation of xerobiotic pollutants and bacterial fertilizers.

V. Practicals

- Determination of soil microbes using classical techniques.
- Determination of soil microbial diversity using molecular techniques.
- Estimation of soil microbial biomass carbon, nitrogen and phosphorus.
- Estimation of key soil enzyme activities.
- Community level physiological profiling of microbial diversity.

VI. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, field visit

VII. Learning outcome

Experience on soil microbial diversity and planning for proper utilization.

VIII. Suggested Reading

- Lynch JM, Willey JM. *Soil Biotechnology*.
- Paul EA and Clark FE. *Soil Microbiology and Biochemistry*.
- Sherwood LM and Woolverton CJ. *Prescott's Microbiology*.
- Subba Rao NS. *Advances In Agricultural Microbiology*.

I. Course Title : Research and Publication Ethics

II. Course Code : Soil 610

III. Credit Hours : 2+0

IV. Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit IV

Publication ethics: Defination, introduction and importance. Best practices/standard setting initiatives and guidelines: COPE, WAME, *etc*., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatory publishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to check publisher copy right and self archiving policies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools, viz., JANE, Elsevier Journal Finder, Springer Journal Suggester etc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open source software tools

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, *etc*. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g index, i10 index altmetrics

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field, laboratory and library visit

VI. Learning outcome

Quality research output and outstanding research publication with excellent impact factor.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Agricultural Physics

Preamble

Agricultural Physics is the discipline dealing with the application of the Principles and laws of Physics in agriculture to study soil, plant and atmosphere for eco-friendly and sustainable exploitation of agricultural resources. Considering the recent advancement of knowledge and the need to make our students to be well aware of the recent developments in Science the syllabi for the discipline of Agricultural Physics was modified. Agricultural Physics is gaining importance in view of its potential to serve as a tool to solve the challenges of feeding a growing population, providing a livelihood for farmers, and protecting the environment. The need for Agricultural Physics as a discipline in M.Sc. and Ph.D. program is emphasized due to the recent applications in crop modelling as a decision tool, satellite remote sensing based near real time crop condition monitoring, drone-based crop disease, pest surveillance, digital soil mapping, artificial intelligence based crop status characterization through image processing, nano biosensors for quick and effective detection and management of crop requirement, etc. This could be possible in future, by starting the M.Sc. and Ph.D. programs in the discipline of Agricultural Physics in all the state agricultural universities and research institutions of ICAR.

In the present syllabus emphasis on knowledge enrichment through field-based studies in the discipline of Agricultural Physics is made by introducing new courses on Satellite Meteorology, Nanotechnology, Image processing and development of sensors for Soil, Crop and Environment Monitoring in agriculture. In view of the various national program like Fasal Bhima Yojana the new modified syllabus for the Agricultural Physics include course content on Remote sensing for crop status monitoring, biomass burning, crop acreage and harvest etc. Similarly, in view of the various Government scheme like Soil Health Card, more crop per drop, etc. Our modified syllabus includes topics on Digital soil mapping, Farmers' participatory GIS, Nanobiosensors for monitoring crop irrigation, fertigation, etc. As per the under New Education Policy 2020, the present syllabus will ensure the students of Agricultural Physics discipline to become holistic individuals with identified set of skillsand values.

The modified syllabus with courses on Physics of Soil and Water Conservation, Fundamentals of Meteorology, General Climatology, Sensors for Soil, Crop and Environment Monitoring and Weather Hazards and its Management are related to the global developments to meet the triple challenges of feeding the growing global population, providing a livelihood for farmers, and protecting the environment. With the rise in the requirement for Biophysics, Remote sensing, nanotechnology, crop simulation modelling, biosensors, big data analytics artificial intelligence, etc. students of the discipline of Agricultural Physics will be a skilled work force as they will have the blend of multidisciplinary ability across the different disciplines of agricultural sciences.

Course Title with Credit Load
M.Sc. in Agricultural Physics

Course Code	Course Title	Credit Hours
AP 501*	Basic Concepts of Agricultural Physics -I	2+1
AP 502*	Basic Concepts of Agricultural Physics -II	3+0
AP 503	Fundamentals of Soil Physics	2+1
AP 504*	Mathematics in Agriculture	3+0
AP 505	Fundamentals of Meteorology	2+1
AP 506*	Principles of Biophysics	2+1
AP 507	Principles of Remote Sensing	2+1
AP 508	Physics of Soil and Water Conservation	2+1
AP 509	General Climatology	2+1
AP 510	Soil Physical Environment and Plant growth	2+1
AP 511	Simulation of Soil, Plant and Atmospheric Processes	2+1
AP 512	Principles of Physical techniques in agriculture	2+1
AP 513	Principles and Applications of GIS and GPS	2+1
AP 514	Nanoscience and Technology for Agriculture	2+0
AP 515	Remote Sensing in Agriculture	2+1
AP 591	Master's Seminar	1+0
AP 599	Master's Research	30

*the core courses compulsorily to be taken

Course Contents
M.Sc. in Agricultural Physics

I. Course Title : Basic Concepts of Agricultural Physics-I

II. Course Code : AP 501*

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the concepts of Agricultural Physics and physics laws.

V. Theory

Unit I

Relevance of Linear, circular, relative motions, conservation of mass, energy and momentum, forces in nature, range of their operation, action at a distance, gravitational field, potential, in agriculture.

Unit II

Concepts of Elasticity, stress-strain relations – moduli of elasticity, Hooke's law, molecular and structural basis of strengths of materials, hydrostatic pressure; surface tension, capillary rise, contact angle, hydrodynamics – laminar and streamline flow, Poiseuille's equation, Stoke's law and their application in agriculture.

Unit III

Principles of Thermometry, measurement of heat, specific heat, transfer of heat - conduction, convection and radiation, Change of phase, equation of state, vapour pressure and relative humidity, laws of thermodynamics, free energy, chemical potential along with their importance in agriculture.

Unit IV

Concepts of Kinetic theory of gases, Brownian motion, mean free path, simple harmonic motion, concepts of phase, phase difference, interference and reflection of sound waves, ultrasonic, along with their relevance in agriculture.

Unit V

Agricultural significance of Wave theory of light, Huygen's principle, reflection, refraction, diffraction, polarization, interference and scattering of light waves; electromagnetic theory of light, geometrical optics, aberrations, resolving power, principles of optical instruments, illuminated and luminous objects and light sources; luminescence, incandescence, fluorescence, auto-fluorescence, phosphorescence, bioluminescence, qualitative and quantitative measurement of light, colour, optical spectrometry.

Unit VI

Principles of Electric charges, potential, field, intensity and strength of electric field, current, Coulomb's law, dielectrics, capacitance, electrostatic units, resistance, resistivity, Ohm's law, steady currents in conductors, insulators and semi-conductors, magnetic materials, induced magnetism, electromagnetism, measurement of magnetic field, geomagnetism, effects of the earth's magnetic field on life, electromagnetic inductions and applications in agriculture

VI. Practical

Use of the instruments in agriculture: Vernier/ Screw Gauge/ Spherometer, Sextant, Surface Tension, Viscosity, Interference Phenomenon, Optical Instruments (diffraction grating), Resistivity measurement (Potentiometer/ Wheatstone bridge), Young's Modulus.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge ofprinciples and loaws of Physics and their application in agriculture

IX. Suggested Reading

- Rose CW, Ashhurst W, Flint HT. (Eds). 1966 *Agricultural Physics*. ISBN: 9781483139258, p. 248.
- Halliday D, Resnick R, Walker J. *Fundamentals of Physics.*
- Young HD, Freedman RA. *University Physics with Modern Physics.*
- Feynman RP, Leighton RB and Sands M. *The Feynman Lectures on Physics*
- Kittel C, Knight W and Ruderman MA. *Berkeley physics course: Mechanics* Vol. 1.
- Purcell EM. *Berkeley physics course: Electricity and Magnetism*, Vol. II.
- Crawford FS, Jr. *Berkeley physics course: Waves.* Vol. III
- Krishna R. 1960. *General Properties of Matter*, Kitab Mahal, Allahabad.
- Mathur DS. 1956. *Elements of Properties of Matter*, S Chand & Co, New Delhi.
- Sengupta PC and Kohli BS. 1967. *Text Book of Physics*, Vol I, II, Kitab Ghar, New Delhi.

I. Course Title : Basic Concepts of Agricultural Physics-II

II. Course Code : AP 502*

III. Credit Hours : 3+0

IV. Aim of the course

To impart knowledge on the concepts of Agricultural Physics and physics laws.

V. Theory

Unit I

Agricultural relevance of Maxwell's theory of electromagnetism, Atomic structure, Avogadro hypothesis and molecules, Atomic and molecular weights, atomic sizes, Quantum mechanics: uncertainty principle, De-Broglie hypothesis, Wave function, Eigen state, Schrodinger equation.

Unit II

Principles of Spectroscopy: atomic and molecular spectra, Spectroscopy: atomic and molecular spectra, Cathode rays; positive rays; Radio activity; alpha-, beta-, and gamma-rays; Rutherford's theory of the scattering of alpha particles; X-rays, nature and properties; scattering of X-rays by atoms; Diffraction of X-rays and Bragg's law; characteristic X-ray spectra.

Unit III

Principles of Quantum theory in agriculture: Planck's quantum theory of thermal radiation; Quantum theory and Photo-electric effect; Elements of special theory of relativity, Atomic Nucleus and its constitution, Angular momentum of the nucleus; Nuclear transmutation of elements; proton-neutron hypothesis; Cosmic rays; elementary particles.

Unit IV

Radioactivity in agriculture: Natural radioactivity, types of radiations Interaction of radiation with matter and decay; Isotopes; isotopic masses and abundances; mass spectrograph; Stable isotopes; atomic masses, packing fractions & binding energy, Theory of radioactive disintegration; half-life and mean life; Mass spectrometers

Unit V

Application of radioactivity in agriculture: Nuclear fission, fusion, Nuclear reactions, neutron moderation, Nuclear energy, atomic power; Production of artificial isotope. Physical principles of Radiation detection; Types of radiation detectors; efficiency of detectors; Uses of radiation detectors, Elements of radioactive sources, handling, Radiation protection and cardinal principles of radiation safety.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge ofphysics and its application in soil, plant and atmospheric continuum.

VIII. Suggested Reading

- Chandrasekharan H and Gupta N. 2006. *Fundamentals of Nuclear Science: Application in Agriculture*, Northern Book Centre, New Delhi.
- David H, Robert R, Jearl W. *Fundamentals of Physics*
- Young HD, Freedman RA. *University Physics with Modern Physics*
- Feynman RP, Leighton RB and Sands M. *The Feynman Lectures on Physics*
- Wichmann EH. *Berkeley physics course: Quantum physics.* Vol IV
- Slater John C. 1960. *Quantum Theory of Atomic Structure*, Vol.1, McGraw Hill, New York.
- Burcham E. 1995. *Nuclear Physics*, ELBS/Longman.
- Kapoor SS and Ramamurthy VS. 1986. *Nuclear Radiation Detectors*, Wiley Eastern Ltd, New Delhi.
- Pochin E. 1983. *Nuclear Radiation: Risks and Benefits*, Clarendon Press, Oxford.
- Rajam JB. 2000. *Atomic Physics*, S Chand and Co, New Delhi.
- Any Graduate level Text book of Physics, Lecture notes/hand-outs given in selected classes

I. Course Title : Fundamentals of Soil Physics

II. Course Code : AP 503

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge (both theoretical and practical) of the physical aspects of the soil and explains the processes of retention and transport of water, solute, heat and air in soil and their role for its proper management.

V. Theory

Unit I

Soil as a disperse polyphase system; mass-volume relationships of soil constituents; sample problems.

Unit II

Soil texture; nature and behaviour of soil particles; textural classes; particle-size analysis.

Unit III

Soil structure- genesis, classification and evaluation; soil aggregation and dispersion; soil conditioners; soil tilth.

Unit IV

Consistency; consistency limits; soil strength and its measurement; swelling and shrinkage; soil compaction; soil crusting; phenomenon and implications.

Unit V

Soil water retention; soil water constants; energy concept of soil water; different components of soil water potential; measurement of soil water content and potential; soil moisture characteristics; hysteresis.

Unit VI

Flow of water in soils; saturated and unsaturated flow; hydraulic conductivity of soils; soil-water diffusivity; measurement of saturated and unsaturated hydraulic conductivity.

Unit VII

Infiltration, redistribution and evaporation of water; soil water balance; permeability; drainage.

Unit VIII

Soil aeration and its characterization; measurement of soil aeration; gaseous diffusion; factors affecting.

Unit IX

Soil temperature and significance; thermal properties of soils; energy balance and mode of heat transfer in soils; factors affecting soil temperature; measurement of soil temperature; management of extreme soil temperatures.

VI. Practical

- Particle-size analysis by hydrometer method and international pipette method
- Determination of particle density and bulk density of soils
- Soil water content determination
- Measurement of soil water potential by using tensiometer
- Soil-moisture characteristics
- Aggregate analysis by wet and dry sieving methods
- Measurement of Atterberg limits
- Measurement of soil strength
- Determination of saturated and unsaturated hydraulic conductivity
- Determination of infiltration rates

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Baruah TC and Barthakur HP. 2001. *Textbook of Soil Analysis*. Vikas Publishing House Pvt. Ltd, New Delhi.
- Ghildyal BP and Tripathi RP. 1987. *Soil Physics*. Wiley Eastern and New Age International, New Delhi.
- Hillel D. 1980. *Applications of Soil Physics*. Academic Press, New York.
- Hillel D. 1998. *Environmental Physics*, Academic Press, New York.
- Jury WA, Gardner W and Horton R. 2004. *Soil Physics*. John Wiley and Sons, New York.
- Klute A. (Ed). 2006. *Methods of Soil Analysis*. Part 1. *Physical and Minerological Methods* (SSSA Book Series No. 5), ASA and SSSA, Madison, Wisconsin.
- Lal R and Shukla MK. 2004. *Principles of Soil Physics*, Marcel Dekker, New York.
- Warrick AW. (Ed). 2002. *Soil Physics Companion*, CRC Press, Boca Raton.

I. Course Title : Mathematics in Agriculture

II. Course Code : AP 504*

III. Credit Hours : 3+0

IV. Aim of the course

To impart the theoretical and practical knowledge of mathematical concept in agriculture.

V. Theory

Unit I

Vectors, matrices and determinants, inversion of matrices, Eigen values and Eigen vectors, Orthogonality, Grahm-Schmidt processes, least square problems.

Unit II

Trigonometric functions and relations.

Unit III

Differentiation, Integration, Integration, applications, linear equations, Non-linear equations, Polynomials, Partial differential equations.

Unit IV

System of coordinates, Cartesian, cylindrical, spherical and polar coordinates, Three-dimensional geometry, Relative motion of frame of reference.

Unit V

Probability, probability distributions and applications, Curve fitting, Regression, Correlation, Linear and non-linear.

Unit VI

Geo-statistics, Averaging and scaling methods, Fourier analysis, Numerical approximation, Numerical analysis, finite element method, Monte carlo analysis, Stochastic methods, Iterative and optimal techniques.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of mathematics in developing models in relation to plant growth, soil dynamics and atmospheric processes.

VIII. Suggested Reading

- Pal SK. *Statistics for Geoscientist-Techniques and application*
- Reddick HW. *Advanced Mathematics for Engineers*
- Ray M and Sharma HS. *Mathematical statistics*
- Wylie CR. *Advanced Engineering Mathematics*

I. Course Title : Fundamentals of Meteorology

II. Course Code : AP 505

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge about basic physical processes in the atmosphere which have direct and indirect relevance to agriculture.

V. Theory

Unit I

Atmosphere and its constituents, weather and climate; meteorology- meaning and scope; historical development; meteorological elements, instruments for measurement of meteorological elements; different branches of meteorology.

Unit II

Meteorological observatory and its classes; theory and working principles of surface meteorological instruments; automatic weather station; meteorological organizations – IMD, NCMRWF, IITM, WMO.

Unit III

Sun and earth; solar radiation and Laws of radiations-Plancks law, Stefan-Boltzman Law, Wiens displacement law, Kirchoffs law, solar constant; radiation receipt on earth surface; atmospheric and astronomical factors affecting solar radiation; ozone hole; albedo and net radiation sensible and latent heat, direct and diffuse radiation; radiation balance of the earth and atmosphere.

Unit IV

Thermal profile of the atmosphere; variation of pressure with height; hydrostatic equation and its application in atmosphere; geopotential, standard atmosphere, altimetry; concept of specific heat at constant volume and pressure; First and second law of thermodynamics, gas laws.

Unit V

Atmospheric moisture, vapour pressure, relative humidity, absolute humidity, specific humidity, mixing ratio, dew point temperature, vapour pressure deficit, psychromatric equations, T-phi diagram; lapse rates; Vertical stability of atmosphere, Virtual and potential temperature, moist and dry adiabatic process; tropical convection.

Unit VI

Atmospheric motion; balancing forces- pressure gradient and Coriolis forces; isobar; pressure systems; geostrophic, cyclostrophic, thermal and gradient winds; trough, ridge and col; Divergence and vertical motion Rossby, Richardson, Reynolds and Froude numbers.

Unit VII

Cyclonic and anticyclonic motions, tropical and extra-tropical cyclones and their structure, cyclone tracks over Indian regions; Air masses and fronts; Land and sea breeze; Mountain and valley winds.

Unit VIII

Clouds and their classification, theories of cloud formation, condensation nuclei, precipitation processes; artificial rain making, thunderstorms and dust storms; haze, mist, fog and dew, hail, hail suppression, fog and cloud – dissipation.

Unit IX

Weather charts and its reading, weather forecasting – now-cast, short, medium and long-range forecasting, numerical weather prediction; synoptic charts and synoptic approach to weather forecasting. Meteorological satellites for weather forecasts; forecast of Indian monsoon rainfall.

VI. Practical

- Visit to meteorological observatory; meteorological instruments, Recording of weather parameters;
- Calculation of daily, weekly and monthly statistics;
- Exploration of meteorological websites – IMD, NCMRWF, IITM and WMO;
- Calculation of standard meteorological weeks and Julian days;
- Visual classification of clouds;
- Understanding synoptic weather charts;
- Climatic normal, climatic chart and identification of low and high pressure systems.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

X. Suggested Reading

- Barry RG and Chorley RJ. 1982. *Atmosphere Weather and Climate*. ELBS (UK).
- Byers HR. 1959. *General Meteorology*. McGraw Hill (New York).
- Ghadekar SR. 2001. *Meteorology*. Agromet Publishers (Nagpur)
- Ghadekar SR. 2002. *Practical Meteorology*. Agromet Publishers (Nagpur).
- Menon PA. 1989. *Our Weather*. NBT (New Delhi).
- Petterssen S. 1958. *Introduction to Meteorology*. McGraw Hill (New York).
- Trewartha GT. 1954. *An Introduction to Climate*. McGraw Hill (New York).

I. Course Title : Principles of Biophysics

II. Course Code : AP 506*

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge of interactive effects of various physical forces on life processes and their applications.

V. Theory

Unit I

Introduction and scope of biophysics, Weak and strong interactions in biological systems, Structure and property of water, Physical, chemical and biological origin of life

Unit II

Experimental techniques used for separation and characterization of bio-molecules: sedimentation, ultra-centrifugation, diffusion, osmosis, viscosity, polarization and electrophoresis, chromatography, amino acid and nucleotide sequence analysis.

Unit III

Spectroscopic techniques for bio-molecular characterization: UV-Visible, IR, NMR, EPR spectroscopy, X-ray diffraction & its application in biology

Unit IV

Physics of photosynthesis, transpiration, chlorophyll fluorescence, principles of thermal and fluorescence imaging and its application in agriculture

Unit V

Principles of magnetic seed treatment and its application in agriculture, Transport phenomena in biological systems, active and passive transport; absorption and germination kinetics of seeds, tissue water status and its characterization by NMR, principles of NIR and its application in non-destructive characterization of grain quality

Unit VI

Fiber physics; strength, physical properties, micronaire, elastic properties, tensile strength, thermal resistance, water absorption, breaking, elongation, crystallinity

Unit VII

Bio-energetic- First and second laws of thermodynamics- Heat, work, entropy and free energy, Concept of negative entropy & its application in living systems; Information theory.

VI. Practical

- Spectroscopy-Verification of Beer-Lambert's law;
- Spectroscopy-Absorption spectrum of chlorophyll a & b;
- Viscometer-Measurement of intrinsic viscosity and molecular mass;
- Polarimeter-Measurement of molar rotation;
- Measurement of leaf water potential;
- Measurement of Osmotic potential of seed;
- NMR spectroscopy- Relaxation time measurements, NMR Spectroscopy oil content measurement;
- Leaf Photosynthesis, Measurement of LAI.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on biological parameters in relation to crop development and yield

IX. Suggested Reading

- Cotterill RMJ. 2002. *Biophysics- An Introduction*, John Wiley & Sons, Ltd.
- Daniel M. 2005. Agrobios. *Basic Biophysics for Biologists.*
- Narayanan P. 2003. *Essentials of Biophysics* New Age International Publishers.
- van Holde KE, Johnson WC and P Shing Ho. 2006. *Principles of Physical Biochemistry.* Printice-Hall International, Inc.
- Wilson K and Walker J. *Practical Biochemistry-Principles and Techniques* Cambridge University Press.

I. Course Title : Principles of Remote Sensing

II. Course Code : AP 507

III. Credit Hours : 2+1

IV. Aim of the course

To teach about basic principles and techniques of remote sensing and introduce its applications.

V. Theory

Unit I

Introduction, electromagnetic radiation, electromagnetic spectrum, physics of remote sensing, radiation interactions with the atmosphere and target, radiometric quantities, BRDF/BRF, remote sensing systems, characteristics of images

Unit II

Platforms, orbits, classification of sensors, satellite characteristics, pixel size, and scale, spectral, radiometric and temporal resolution

Unit III

Spectral signatures of natural targets in optical and thermal regions, physical basis of signatures, spectral indices.

Unit IV

Imaging and nonimaging systems, multispectral imaging, hyperspectral imaging, thermal imaging, microwave and LIDAR, Fluorescence imaging, aerial remote sensing

Unit V

Weather, land, ocean and other observation satellites, Indian remote sensing satellites, data reception, data products

Unit VI

Thermal remote sensing: Principles, signature, measurements, IR detection and imaging technology

Unit VI

Microwave remote sensing: principles, signatures, interferometry, radar basics, viewing geometry and spatial resolution, image distortion, target interaction, image properties.

Unit VII

Image analysis: Visual interpretation, digital image processing, pre-processing, enhancement, transformations, classification, accuracy, integration, processing of multispectral, hyperspectral, thermal and microwave images.

Unit VIII

Overview of remote sensing applications in earth resource management: agriculture, meteorology, forestry, land cover/land use, water resources

VI. Practical

- Use of Spectroradiometer, Use of FTIR, Spectral signatures of different materials; Derivation and analysis of vegetation indices;
- Analysis of emissivity spectra;
- Familiarization with satellite imagery (FCC);

- Visual Image Interpretation;
- Satellite data acquisition and satellite Data Receiving Station;
- Digital Image processing – Introduction to software, GPS and Ground truth Collection;
- Digital image processing: Pre-processing, Enhancement and training site collection, classification and Post Classification Accuracy Assessment.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and their utility in research for solving field problem.

IX. Suggested Reading

- Campbell JB. 1996. *Introduction to Remote Sensing*, 2nd ed., The Guilford Press, New York.
- Colwell RN. (Ed.) 1983. *Manual of Remote Sensing*, Vol.I, American Society of Photogrammetry, Falls Church, Va.
- Curran PJ. 1985. *Principles of Remote Sensing*, Longman, London.
- David L Verbyla. 1995. *Satellite Remote Sensing of Natural Resources*, Lewis Pub.
- George Joseph. 2005. *Fundamentals of Remote Sensing*, 2nd ed., University Press.
- Jansen JR. 2004. *Introductory Digital Image Processing: A Remote Sensing Perspective*, 3rd ed., Prentice Hall.
- Lilisand TM, Kiefer RW and Chipman JW. 2003. *Remote Sensing and Image Interpretation*, 5th ed., John Wiley & Sons, Inc., New York.
- Panda BC. 2008. *Principles and Applications of Remote Sensing*, Viva Publications.
- Sabins FF. 1996. *Remote Sensing: Principles and Interpretations*, 3rd ed., W.H. Freeman.

I. Course Title : Physics of Soil and Water Conservation

II. Course Code : AP 508

III. Credit Hours : 2+1

IV. Aim of the course

To teach about extent and significance of different forms of soil erosion and their control measures.

V. Theory

Unit I

History of soil erosion; geological and accelerated erosion; agents of soil erosion; acceptable limits of soil erosion.

Unit II

Physics of soil erosion by water; types of water erosion - sheet erosion, splash erosion, rill erosion, gully erosion; specialized forms of soil erosion- pedestal erosion, pinnacle erosion, piping, slumping.

Unit III

Soil erodibility; factors affecting soil erodibility - soil physical characteristics, land management, crop management; soil erodibility indices; empirical constants.

Unit IV

Rainfall erosivity; estimation of rainfall erosivity - EI_{30}index and kinetic energy, and their calculations; erosivity indices.

Unit V

Runoff measurements – current meters, flumes, weirs and orifice, stage level recorder, hydrographs; runoff estimation - quantities and rates of runoff, Rational formula, Cook's method.

Unit VI

Sediment measurement - multiplot divisor, Coshocton wheel sampler, point and depth integrated sediment samplers; universal soil loss equation; estimation of soil loss and its prediction.

Unit VII

Physics of wind erosion - wind velocity, initiation and movement of soil particles; saltation, suspension and surface creep; soil physical properties affecting wind erosion.

Unit VIII

Overview of soil and water conservation in India; soil and water conservation research; techniques for soil and water conservation for agricultural and non-agricultural land - use of mechanical structures and biological methods; wind erosion control.

Unit IX

Concept of watershed development and management - size and shape of watershed; characterization and management of watersheds using remote sensing and GIS; understanding concept of integrated watershed management through case studies.

VI. Practical

- Determination of soil erodibility indices - suspension percentage, dispersion ratio, erosion ratio, clay ratio, clay/moisture equivalent ratio, percolation ratio, raindrop erodibility index; computation of kinetic energy of falling rain drops
- Measurement of land slope using Abney's level
- Computation of rainfall erosivity index (EI_{30}) using rain gauge data
- Estimation of surface runoff/water flow using different techniques
- Estimation of soil losses
- Visit to a watershed

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil water environment and their utilization in crop growth

IX. Suggested Reading

- Fangmeier DD, Elliot WF, Wookman SR, Huffman RL and Schwab GO. 2006. *Soil and Water Conservation Engineering*. Delmer Learning.
- Flanagan DC. (Ed.). 1990. *WEPP* Second Edition, USDA-Water Erosion Prediction Project; Hill Slope Profile Model Documentation Corrections and Additions. NSERL Rpt. No. 4. National Soil Erosion Res. Services, USDA.
- Hudson N. 1995. *Soil Conservation*. Iowa State University Press.
- Pierce FJ and Frge WW. 1998. *Advances in Soil and Water Conservation*. CRC Press.
- Renald KG, Foster GR, Weesies GA, Cool DK and Yoder DC. 2000. *Predictory Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*. Agricultural Handbook AH 703. USDA.

- Singh G, Babu R and Chandra S. 1981. *Soil Loss Prediction Research in India*. Central Soil and Water Conservation Research and Training Institute, Dehradun. Bull. No. T12/D9.

I. Course Title : General Climatology
II. Course Course : AP 509
III. Credit Hours : 2+1

IV. Aim of the course

To learn about the climatic controls, climatic classifications, and their relevance in agriculture

V. Theory

Unit I

Sun and earth, solar system, solar constant; latitudes and longitudes of the earth, seasons, rotation and revolution, solstices and equinoxes, radiation receipt on earth surface, radiation balance of the earth and atmosphere.

Unit II

Earth's environment- atmosphere, hydrosphere, lithosphere and biosphere: Atmospheric constituents: Weather and climate- weather and climatic elements.

Unit III

Climatic controls, latitudinal and seasonal variation of insolation, temperature, pressure belts & wind system, precipitation.

Unit IV

Climatic classification: Koppen and Thornthwaite systems, Hargreaves, Troll, Trewartha and Papadakis systems. Climatic types- continental, maritime and monsoon climate; climatic indices, climatic zones.

Unit V

Climatology of India; monsoons -origin, branches onset, progress and withdrawal of south-west monsoon monsoon breaks, rainfall variability; El Nino, La Nina, QBO (quasi-biennial oscillation) and ENSO and their impacts on Indian economy. North-east monsoon. North- western disturbances and nor 'wester shower.

Unit VI

Climate change and global warming, disastrous weather and climatic events in different regions and their frequencies. Heat & cold wave, frost, dust storm, lightning & thunderstorm, cyclone, cloud burst, drought and flood - their impacts on public life and agriculture.

Unit VII

Drought climatology- Concept, definition, types of drought and their causes; rainfall and its variability, intensity, duration, beginning and end of drought and wet spells; moisture availability indices; Monitoring of drought; drought indices, crop water stress index, crop stress detection;

VI. Practical

- Calculations of climatic normal;
- Determination of climate type of particular station using different climate classification systems;

- Rainfall probability analysis;
- Computation of drought indices;
- Indices for extreme weather events;
- Climatic water balance for climate classification.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

IX. Suggested Reading

Books

- Barry RG and Chorley RJ. 1982. *Atmosphere Weather and Climate*. ELBS (UK)
- Critchfield HJ. 1982. *General Climatology*. Prentice Hall of India (New Delhi).
- Das PK. 1995. *The Monsoon*. NBT (New Delhi).
- Haurwitz B and Austin JM. 1944. *Climatology*. McGraw-Hill.
- Lal DS. 2011. *Climatology* Sharda Pustak Bhavan, (Allahabad).

Journals

- *Journal of Climate*
- *International Journal of Climatology*
- *Climate and Development*
- *Climate Change*
- *Nature- Climate Change*

I. Course Title : Soil Physical Environment and Plant Growth

II. Course Code : AP 510

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about characterization and management of soil physical environment in relation to plant growth and yield.

V. Theory

Unit I

Introduction: Effect of soil physical properties on plant growth - soil water, soil air, soil temperature, mechanical impedance and tillage practices.

Unit II

Soil water: Soil moisture – plant water relations, available water, newer concepts of water availability, least limiting water range, soil-plant-atmosphere system as a physical continuum, plant uptake of soil moisture, evaporation, transpiration and evapotranspiration, dynamics of water in the soil-plant-atmosphere continuum.

Unit III

Root growth – germination and seedling emergence, hydraulic properties of roots, characterization of root growth parameters, water balance of the root zone, soil physical properties and root growth, flow of water to roots.

Unit IV

Soil Temperature – effect of soil temperature on plant growth, soil temperature management, thermal regimes, mulching, radiation – heat budget and energy balance in the field, radiation use efficiency, radiation exchange in the field, exchange of heat and vapour to the atmosphere.

Unit V

Aeration – critical oxygen concentration and factors affecting.

Unit VI

Field water balance – field water balance, irrigation and water use efficiency, consumptive use, plant uptake of soil moisture

Unit VII

Nutrient uptake and use by plants, managing soil physical condition for improved nutrient use efficiency, integrated nutrient management in relation to soil physical condition.

Unit VIII

Resource conservation technologies- bed planting & zero-tillage - types, suitability and effect on soil physical properties, other resource conservation technologies and the impact (short and long term) on soil health.

Unit IX

Modelling: Interactions of soil, management and climatic factors on plant growth, development of sustainability indices.

VI. Practical

- Measurement of penetration resistance and LLWR, Plant water potential;
- Field saturated hydraulic conductivity, transpiration using Porometer;
- Root Length Density, Root Diameter, Root weight using Root Scanner, plant N content;
- Germination percentage as affected by temperature;
- Estimation of evapotranspiration losses, estimation of consumptive water use, production functions, field water balance components, water uptake by plants.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on soil physical environment to solve field problem

IX. Suggested Reading

- Doorenbos J and Pruitt WO. 1975. *Crop Water Requirements*. FAO Irrigation and Drainage Paper 24. Rome.
- Hanks and Ascheroft. 1980. *Applied Soil Physics*. Springer Verlag.
- Hillel D. 1971. *Soil and Water: Physical Principles and Processes*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physics*. Academic Press. Slatyer RO. 1967. P*lant- Water Relations*. Academic Press.

I. Course Title : Simulation of Soil, Plant and Atmospheric Processes

II. Course Code : AP 511

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of using simulation models for crop-environment interactions

V. Theory

Unit I

Fundamentals of dynamic simulation, systems, models and simulation.

Unit II

Descriptive and explanatory models, modelling techniques steps, states, rates and driving variables, feedbacks and relational diagrams.

Unit III

Numerical integration, introduction to FST language.

Unit IV

Modelling crop environment and crop pest interactions, soil water, nitrogen and balance, introduction to a simple crop ecological model, applications of simulation modelling in environmental impact assessment and greenhouse gas emission.

Unit V

Data requirements and limitations of modelling; modelling crop-environment and pest interaction, soil, water, nitrogen and C balance; assessing crop growth, scheduling and management practices and water use planning through simulation tools.

VI. Practical

- Scheduling planting and harvesting of crops;
- Drawing relational diagrams;
- Applying numerical integration techniques;
- Fitting probability distribution functions;
- Hands on model validation through statistical indices;
- FST programming language;
- Hands on to InfoCrop model;
- Assessing crop growth through InfoCrop model;
- Hands on to USAR model, Crop rotation & water use planning through USAR model.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on simulation model for solving problems in field.

IX. Suggested Reading

- Cox GW, Atkins MD. 1979. *Agriculture Ecology*. Freeman & Co.
- Etherington JR. *Environmental and Plant Ecology*. John Wiley Sons.
- Mitchell R. *The analysis of Indian agro-ecosystem*.
- Odum OP. *Ecology*. Oxford & IBM Publishing Co.
- Sinclair TR and Gardener FP (Eds). *Principle of ecology in plant production*. CABI, UK.

I. Course Title : Principles of Physical Techniques in Agriculture

II. Course Code : AP 512

III. Credit Hours : 2+1

IV. Aim of the course

To educate about different optical, electrical, colorimetric and nuclear techniques used in agriculture.

V. Theory

Unit I

Principles of measurements; laboratory, field and regional scales.

Unit II

Principles of optical and polarized microscopes; reflection, transmission and absorption in relation to properties of object; colorimetric techniques; single and double beam instruments; spectrophotometry; Beer and Lambert law; fluorescence; Raman spectra.

Unit III

Sensors and transducers; principles of leaf area meter, canopy analyser, quantum sensor, Spectro-radiometer, laser land leveller; photosynthetic system analyser for determination of plant water and photosynthetic parameters.

Unit IV

Principles of infrared thermometry; thermal imaging, emissivity laws; characteristics of agricultural materials.

Unit V

Principles of X-ray and its applications in clay mineralogy; small angle scattering.

Unit VI

Principles and applications of electron microscopes; transmission and scanning electron microscopes; confocal microscope and its applications.

Unit VII

Atomic absorption spectroscopy - principles, detection limits and sensitivity.

Unit VIII

Nuclear techniques - detection and measurements of charged particles, radiation monitoring instruments, radiation hazards evaluation and protection. Tracer methodology - isotopes and their applications in agriculture, gamma irradiation for genetic variability

Unit IX

Concepts of Nano Science and technology and their applications in agriculture

Unit X

NMR, NIR, mass spectrometer - principles and applications.

V. Practical

- Discharge of electricity through gases
- Ionization current measurements
- Photoelectric effect and measurements
- Geiger Muller counter- quenching time
- Thickness measurement of thin films/ foils/ paper sheets
- Half-life determination
- Tracer applications of artificial radionuclides
- Multi-channel analyser
- Neutron moisture meter
- Use of NMR spectrometer
- Seed irradiation with gamma rays
- Radiocarbon dating.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Basic knowledge on, electrical, colorimetric and nuclear techniques used in agriculture.

VIII. Suggested Reading

- Arnikar HJ. 1989. *Isotopes in the Atomic Age*. Wiley Eastern.
- Bhaskaran S, Ghosh SK and Sethi GR. 1973. *Proceedings of the International Symposium on Use of Isotopes and Radiation in Agriculture and Animal Husbandry Research,* Nuclear Research Laboratory, IARI, New Delhi.
- Broetjes C. 1965. *The Use of Induced Mutations in Plant Breeding*. Pergamon Press.
- Burcham E. 1995. *Nuclear Physics*. ELBS/Longman.
- Glasstone S. 1967. *Source Book of Atomic Energy*. Affiliated East West Press.
- Kapoor SS and Ramamurthy VS. 1986. *Nuclear Radiation Detectors*. Wiley Eastern.
- Pochin E. 1983. *Nuclear Radiation: Risks and Benefits*. Clarendon Press.
- Rajan JB. 2000. *Atomic Physics*. S Chand & Co.
- Tiwari PN. 1985. *Nuclear Techniques in Agriculture*. Wiley Eastern. Wolf G. 1964. *Isotopes in Biology*. Academic Press.

I. Course Title : Principles and Applications of GIS and GPS

II. Course Code : AP 513

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on dealing with spatial data and its applications in natural resource management.

V. Theory

Unit I

Introduction; History of cartography and maps.

Unit II

Basic concepts and principles; hardware and software requirements; common terminologies of geographic information system (GIS).

Unit III

Geographical data structures; relational database management system; overview of MS Access.

Unit IV

Maps and projections: principles of cartography; Basic geodesy: Geoid/ Datum/ Ellipsoid; cartographic projections, coordinate systems, types and scales; accuracy of maps.

Unit IV

GIS data collection, linking spatial and non-spatial data; Errors and quality control, data output.

Unit V

Raster based GIS: spatial referencing, definition and representation, data structure, advantages and disadvantages; Vector based GIS: Definition, concept, data structure, capture and Vector and raster formats, vector to raster and raster to vector conversion, advantages and disadvantages

Unit VI

Principles of graph theory, topology and geometry; spatial analysis: statistical analysis, measurement, proximity (buffering), overlay analysis, classification, network analysis, multicriteria analysis, site suitability analysis, nearest neighbour analysis.

Unit VII

Surface modelling: Thiessen polygon, interpolation, DEM; Geostatistical analyses, spatial and non-spatial query.

Unit VII

Software and hardware requirements of GIS; Integrated image analysis and GIS; GIS for modelling.

Unit VIII

Web GIS/ Geoportal, 3D GIS, object-oriented GIS, mobile GIS, knowledge-based GIS; data warehousing, data mining; metadata, data interoperability, open GIS consortium, GIS customization, DSS and SDSS.

Unit IX

Applications of GIS for water resources, agriculture, precision farming, disaster management, e-governance, Agricultural Research Information System (ARIS).

Unit X

Basic Concepts, segments, working principles; Measuring distance and timing, errors in GPS data and correction; Differential GPS; Integration of GPS data with GIS data, use of GPS in remote sensing analysis; Past, present and future status of GPS; Applications of GPS in agriculture and natural resource management.

VI. Practical

- Overview of current GIS software: ArcMap/ArcGIS/QGIS;
- Introduction to MS Access;
- Data input (spatial data); digitization and scanning;
- Data input: editing, Data input: non-spatial attributes and linking with spatial data;
- Database creation and map registration;
- Spatial analysis: Surface modelling, overlaying, buffering, neighbourhood analysis, Coordinate data collection through GPS and its integration with GIS.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and GPS and their utility in research for solving field problem.

IX. Suggested Reading

- Burroughs PA. 1986. *Geographical information systems for land resources assessment.* Oxford University Press
- Chakraborty D and Sahoo RN. *Fundamentals of Geographic Information System*, Viva Books Pvt. Ltd, New Delhi.

- Laurini R and Thompson D. 1992. *Fundamentals of Spatial Information Systems*. London, Academic Press, New York.
- Longley PA, Goodchild MF, Maguire DJ and Rhind DW. 1997. *Geographical Informatics Systems*. II Edition, New York, John Wiley. Online useful materials

Websites

http://www.gisdevelopment.net/tutorials/tuman006.htm
- http://www.colorado.edu/geography/gcraft/notes/datacon/datacon_f.html
- http://egsc.usgs.gov/isb/pubs/gis_poster/ http://www.quantdec.com/SYSEN597/
- http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Tutorials (especially for ArcGIS user)

I. Course Title : Nanoscience and Technology for Agriculture

II. Course Code : AP 514

III. Credit Hours : 2+0

IV. Aim of the course

To impart basic knowledge about nanoscience, properties of nanoparticles and their applications in biology.

V. Theory

Unit I

Outline of the course; Nanostructure: growth of compound semiconductors, super lattices, self-assembled quantum dots, Nano-particles, nano tubes and Nano wires, fullerenes (buck balls, grapheme), Nanofabrication and nano-patterning; Optical, X-ray, and electron beam lithography, self-assembled organic layers, Process of synthesis of nano powders, Electro-deposition, Important nano materials.

Unit II

Mechanical properties, Magnetic properties, Electrical properties, Electronic conduction with nano particles, Investigating and manipulating materials in the nanoscale; Electron microscopy, scanning probe microscopy, optical microscopy for nano science and technology, X-ray diffraction, scanning tunnelling microscopy, atomic force microscopy.

Unit III

Nano-biology: Interaction between biomolecules and nano-particle surface, Different types of inorganic materials used for the synthesis of hybrid nano-bio assemblies. Applications of nano in agriculture, current status of nano biotechnology, Future perspectives of Nanobiology, Nano sensors.

Unit IV

Types of nanomaterial hazard their identification, toxicity and exposure assessment, threshold limit, characterization, health risk assessment.

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VI. Learning outcome

Experience on the knowledge of nano science and their utility in agricultural research.

VII. Suggested Reading

- Balndin AA and Wang KL. (Ed.) 2006. *Handbook of semiconductor nanostructure and nanodevices*. American Scientific Publishers, California.
- Challa Kumar (Ed.). 2006. *Nanotechnologies for the life sciences*. Willey-VCH GmbH, Weinheim.
- Gregory Timp. 1999. *Nanotechnology*. Springer Verlag, New York.
- Margaret E Kosal. 2009. *Nanotechnology for chemical and biological defence*. Springer, Dordrecht.
- Michael Kohler and Wolfgang Frintzsche. 2007. *Nanotechnology: Introduction to nano structuring techniques*. Wiley-VCH Verlag GmbH, Weinheim.

I. Course Title : Remote Sensing in Agriculture (Pre-requisite AP 507 Principles of Remote Sensing)

II. Course Code : AP 515

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about the remote Sensing techniques and their applications in agriculture.

V. Theory

Unit I

Scope of remote sensing in agriculture, sensors platforms and data availability for agricultural remote sensing and recent developments.

Unit II

Remote Sensing of soil spectroscopy of soils, differentiation and identification of soils, soil parameters by hyperspectral remote sensing, soil survey and resource mapping, soil health.

Unit III

Crop identification and discrimination, crop acreage estimation, monitoring of crop growth and phenology, yield modelling and forecasting.

Unit IV

Retrieval of crop biophysical parameters – empirical and radiative transfer approaches, assessing crop abiotic and biotic stresses, monitoring agricultural drought and early warning, crop loss assessment and insurance using remote sensing.

Unit V

Land use/ land cover mapping and change detection analysis, land use modelling, cropping system analysis land planning with reference to different agro eco-regions, land degradation process (Salinity, waterlogging, etc) and their evaluation by remote sensing.

Unit VI

Role of remote sensing in water resource development and management, identification of ground water potential zones, generation of different thematic maps for integrated watershed management; Microwave remote sensing for crop and soil studies, soil moisture mapping, flood assessment and management by remote sensing.

Unit VII

Precision farming principles - VRT, Modern techniques and machines. Remote sensing for plant phenotyping, post-harvest quality assessment.

VI. Practical

- Use of Infrared thermometry and spectral data for crop stress monitoring;
- Hyperspectral data for soil and crop characterization;
- Computation of Spectral Indices for Soil and Vegetation;
- BRDFs and Radiative transfer modelling, processing of microwave remote sensing data;
- Salinity mapping from remote sensing data; Pre-processing of time series satellite data;
- Crop discrimination and acreage estimation;
- Crop yield modelling from satellite data;
- Land use land cover classification and change detection;
- Drought and crop condition monitoring, processing of image data for plant phenotyping.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and GPS and their utility in research for solving field problem.

IX. Suggested Reading

- Barret EC and Curtis LF. 1982. *Introduction to Environmental Remote Sensing*, Chapman & Hall, London.
- Colwell RN. (Ed.) 1983. *Manual of Remote Sensing*, Vol. II, American Society of Photogrammetry, Falls Church, Va.
- Jensen JR. 2006. *Remote Sensing of the Environment: An Earth Resource Perspective*, 2nd ed., Prentice Hall.
- Narayan LRA. 1999. *Remote Sensing and its Applications,* Oscar Publ.
- Patel AN and Singh S. 2004. *Remote Sensing: Principles and Applications*. Scientific Publ.
- Thenkabail P, Turral H, Biradar C and Lyon JG. (Eds) 2009. *Remote Sensing of Global Croplands for Food Security,* CRC Press.
- Ustin S. 2004. *Remote Sensing for Natural Resource Management and Environmental Monitoring*, 3rd ed., Wiley.

Course Title with Credit Load
Ph.D. in Agricultural Physics

Course Code	Course Title	Credit Hours
AP 601*	Principles of Soil Physics	2+1
AP 602	Applied Soil Physics	2+1
AP 603	Crop Micrometeorology and Evapotranspiration	2+1
AP 604*	Digital Image Processing	1+1
AP 605	Satellite Agrometeorology	2+1
AP 606	Sensors for Soil, Crop and Environment Monitoring	2+1
AP 607	Weather Hazards and its Management	2+0
AP 691	Doctoral Seminar I	1+0
AP 692	Doctoral Seminar II	1+0
AP 699	Doctoral Research	75

*the core courses compulsorily to be taken

Course Contents
Ph.D. in Agricultural Physics

I. Course Title : Advanced Soil Physics (Pre-requisite AP 503 Fundamentals of Soil Physics)

II. Course Code : AP 601

III. Credit Hours : 2+1

IV. Aim of the course

To study the physical processes for transport of water, solute, heat and air in soil using advanced mathematical tools and techniques.

V. Theory

Unit I: Mathematical tools

Vector calculus: gradient, divergence and curl of a vector. Fourier series, Laplace and inverse Laplace transforms and their applications for solving flow and transport equations in soil analytically; Numerical approximations: finite difference methods for solving transport equations. Iterative procedures for solving linear and nonlinear equations, Monte Carlo simulation.

Unit II: Soil water transport

Saturated flow equations: Poiseuille's and Darcy's equations, Laplace equation of steady flow and Poisson equation for unsteady flow, three-dimensional saturated hydraulic conductivity and fluxes, Specific Storage Coefficient, Aquifer Transmissivity, conductance coefficient, Effective hydraulic conductivity for layered soils.

Unsaturated flow equations of Vadose zone: Buckinghum-Darcy equation, Richards equation; Unsaturated flow parameters: Unsaturated Hydraulic conductivity: Models for estimation – Gardener's model, van Genucheten model, Brooks and Corey model and Kosugi model; Capillary Length Scales: Macroscopic and microscopic capillary lengths; Woodings equation for steady infiltration from a shallow ponded ring. Preferential flow: Macropore Flow, fingering and Funnel flow; Measurement of saturated and unsaturated hydraulic conductivity: Lab methods- constant head and falling head methods, Field methods- infiltrometers and permeameters, instantaneous profile and field inverse methods; Numerical models of water flow - finite difference method.

Infiltration models: Empirical models-Kostikov model, Horton model, Physical models - Green-Ampt and Philip models both for horizontal and vertical infiltration, Boltzmann transformation of wetting front for solving water flow during horizontal and vertical infiltration, computation of profile controlled and supply controlled infiltration along with time of ponding, homogeneous and layered soil infiltration, curve number method, preferential flow.

Solute transport: solute transport mechanisms: mass flow, diffusion, hydrodynamic dispersion, miscible and immiscible displacement, hypothetical and experimental breakthrough curves, Convective-Diffusive equation (CDE), linear and non-linear adsorption, solution of CDE, analytical solution by Laplace transformation, numerical solutions by finite difference and finite element methods, applications, methods of determination of dispersion and diffusion coefficients.

Unit III: Soil heat flow

Equation of heat transport by conduction and its sine wave solution, damping depth and its significance. Measurement of soil thermal conductivity by single and dual probe and thermal diffusivity by time lag and amplitude-based methods. Computation of volumetric heat capacity by de Vries method. Soil heat flux measurement by heat flux plates. Estimation of thermal diffusivity by finite difference method.

Unit IV: Movement and exchange of gases in soils

Darcy's law for advective transport (non-isobaric system) of gases, deviation from Darcy's law, gas transport by diffusion in isobaric system (Fick's law). Multi component gas transport- Dusty Gas model, Stefan Maxwell equation. Gas permeability: laboratory and field measurement of gas permeability.

VI. Practical

- Guelph Permeameter for field saturated hydraulic conductivity;
- Hydraulic conductivity by instantaneous profile method;
- Computation of dispersion and diffusion coefficients of CDE;
- Calibration of parameters of Green and Ampt and Philip models and calculation of time of ponding, measuring thermal properties in field;
- Bruce and Klute method for computing hydraulic diffusivity under horizontal infiltration, Modelling water and heat transport in soil.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Daniel Hillel. *Advanced Soil Physics.*
- Kirkham and Powers. *Advanced Soil physics.*
- Warrick AW. *Soil Physics Companion.*

I. Course Title : Applied Soil Physics
(Pre-requisite AP 503 Fundamentals of Soil Physics)

II. Course Code : AP 602

III. Credit Hours : 2+1

IV. Aim of the course

To map soil properties for precision farming, assessment of soil quality, structural problems of different soils and their amelioration through appropriate conservation tillage, soil conditioning.

V. Theory

Unit I: Techniques for mapping soil properties and their use

Classical methods of interpolation: IDW, spline, global polynomial; Geostatistics:

Spatial variability of soil properties: spatial dependence and spatial structure studies – empirical semi variogram and semi variogram models, kriging for interpolation – type of kriging, Geostistical analyst, 3D analyst and spatial analyst tools of GIS for mapping soil properties, Use of soil maps for soil health assessment and reducing input use in precision farming.

Unit II: Assessment of Soil quality

Definitions of soil quality, selection of minimum data set of physical, chemical and biological characteristics for quality assessment, indices of soil quality: Physical rating of soils, least limiting water range (LLWR) as an indicator of structural quality, Proctor compaction test, soil erodibility indices.

Unit III: Soil structural problems of major soil types and their amelioration

Management of highly permeable soils, slow permeable black soils, hardening of redchalka soils, shallow soils, soils with subsurface hardpan, tal lands, paddy soils, soil crusting

Unit IV: Soil tillage

Role of tillage for modification of soil structure, Assessment of site-specific tillage requirement based on soil and climatic properties, conservation tillage, effect of tillage on water and solute transport in soil.

Unit V: Soil conditioners

Water soluble conditioners and soil hydrogels – mode and rate of their application and modification in soil water retention curve of different soil types. Influence of atmospheric demand on hydrothermal regimes of soils with conditioners.

Unit VI: Applications of remote sensing in surface soil moisture estimation:

Estimation of surface soil moisture by thermal and passive microwave techniques

VI. Practical

- Empirical semi variogram and fitting appropriate semi variogram model;
- Preparation of prediction map of a soil property by kriging;
- Soil physical health assessment of a farm;
- Comparison of soil water retention curves of a soil with variable rates of applied conditioner;
- Computation of LLWR under different soil management practices.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Daniel Hillel. *Advanced Soil Physics*.
- Gupta RP and Ghildyal BP. *Soil Structure*.
- Warrick AW. *Soil Physics Companion*.
- ARC GIS manual.

I. Course Title : **Crop Micrometeorology and Evapotranspiration (Pre-requisite AP 505 Fundamentals of Meteorology)**

II. Course Code : **AP 603**

III. Credit Hours : **2+1**

IV. Aim of the course

To impart advanced theoretical and practical knowledge about the physical processes in the atmosphere near the ground for growing crop plants with special emphasis of evapotranspiration process.

V. Theory

Unit I

Micro-, meso- and macro-climates and their importance, Atmosphere near the ground – bare soil and crop surfaces, exchange of mass, momentum and energy between surface and overlaying atmosphere, exchange coefficients, Richardson number & Reynold's analogy, Mixing length theory, boundary layer equations, surface layer, Ekman layer, frictional affects, eddy diffusion, forced & free convection. Wind profile near the ground; roughness and zero plane displacement.

Unit II

Micrometeorology of plant canopies: Radiation, temperature, wind, humidity and carbon dioxide profiles in crops; Influence of topography on microclimate; variation in microclimate under irrigated and rainfed conditions; Micrometeorology of field crops rice and wheat, forest and orchards etc.

Unit III

Hydrological cycle and concept of water balance, concepts of evaporation. evapotranspiration, potential, reference and actual evapotranspiration, consumptive use, different approaches of ET determination by empirical methods, energy balance and Bowen's ratio methods, water balance single and multi-layered soil methods, aerodynamic, eddy correlation and combination approaches, field lysimetric approaches and canopy temperature-based methods; Advantages and limitations of different methods.

Unit IV

Measurement of water use efficiency/water productivity, irrigation scheduling and yield functions; Advective energy determination and its effect on water use by crops; Physiological variation in relation to crop growth and development.

VI. Practical

- Micromet sensors and automatic weather station;
- Global and net radiation diurnal variations;
- Temperature profile, Humidity profile and Wind profile in the crops at different stages;
- Energy balance components for IARI station;
- PET by Thornthwaite's method, Blaney Criddle method, Radiation (Makkink's) method;
- Bowen's Ratio, Aerodynamic method, Combination (FAO-56) method, Pan Evaporation, Lysimeter, Eddy Covariance.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

IX. Suggested Reading

Books

- *Disaster Management in India*, Ministry of Home Affairs, Govt. of India, 2011.
- *Manual of Drought Management*, Ministry of Agriculture, Govt. of India, 2016.
- *Textbook of Disaster Management*, by Nitesh Kumar, Satish Serial Publishing House.

Journals

- *Natural Hazards*
- *Disasters*
- *Agriculture & Forest Meteorology*

I. Course Title : Digital Image Processing (Pre-requisite: AP 507 Principles of Remote Sensing)

II. Course Code : AP 604

III. Credit Hours : 1+1

IV. Aim of the course

To impart advanced technical and practical knowledge about the image processing procedures with emphasis on their applications in agriculture

V. Theory

Unit I

Introduction - Image processing display systems. Initial statistical extraction - univariate and multivariate image statistics, histogram and its significance in remote sensing data. Pre-processing - Introduction, missing scan lies, desk tripping methods, geometric correction and registration, atmospheric corrections, illumination and view angle effects.

Unit II

Image reduction, image magnification, contrast enhancement; linear, non-linear, ratioing, edge enhancement; linear, non-linear; low pass filters, high pass filters, edge detection, point and neighbourhood operation Image transform - Arithmetic operations'-based image transforms, principle component analysis, discriminate analysis. Fourier transforms, Fast Fourier frequency domain filters and vegetation indices.

Unit III

Image compression fundamentals: Coding, interpixel and Psyco-visual redundancy, and fidelity criteria. Image compression models: Source encoder and decoder, channel encoder décor, Elements of information theory: Measuring information, entropy, the information channel fundamental coding theorems and using information theory, Image Fusion.

Unit IV

Image segmentation: Detection of points, lines and edge detection and combined detection Edge linking and boundary detection: Local processing, Global processes via Hough transform; Thresholding: foundation, role of illumination, simple global thresholding, optimal thresholding. Split and merge and Texture based Segmentation.

Unit V

Classification: Geometrical basis, unsupervised & supervised techniques; Advance classification techniques: Use of external data, contextual information, feature - sub-feature study, classification accuracy; Change detection - the nature of change detection, change detection algorithms, image differencing, and image rationing and classification comparisons; Imaging Spectroscopy, Data Processing techniques, data mining techniques, Spectral angle mapping, Spectral unmixing, Construction digital terrain models, Application of DTMs – contour generation, fill, fly though; slope and aspect; viewshed analysis; watershed and drainage extraction; volumetric analysis; preparation of orthoimages

VI. Practical

- Digital Image processing –Introduction to software, MATLAB and R software, Image acquisition;
- Digital image processing: Pre-processing, Enhancement and training site collection, classification;
- Post Classification, Accuracy Assessment;
- Processing of microwave image;
- Processing of thermal image;
- Processing of Hyperspectral image: Pre-processing and classification, Multi-resolution image Fusion.

V. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VI. Learning outcome

Basic knowledge on image processing procedures with emphasis on their applications in agriculture

VII. Suggested Reading

Books

- Gonzalez RC and Woods RE. 2014. *Digital Image Processing*. Pearson.
- Jensen JR. 1986. *Introductory Digital Image Processing: A Remote Sensing Perspective*. Prentice Hall.
- Qihao Weng 2011. *Advances in Environmental Remote Sensing: Sensors, Algorithms and Applications*, CRC Press.

Journal

- *IEEE Trans. Geoscience and Remote Sensing*
- *IEEE Transactions on Image Processing*
- *International Journal of Image Processing - IJIP - CSC Journals*
- *Signal Processing: Image Communication - Journal - Elsevier*

I. **Course Title** : **Satellite Agrometeorology**
(Pre-requisite: AP 505 Fundamental of Meteorology)
II. **Course Code** : **AP 605**
III. **Credit Hours** : **2+1**

IV. **Aim of the course**

To learn the use of satellite images for retrieval agro-meteorological parameters and their applications in agriculture.

V. **Theory**

Unit I

Scope and importance of agrometeorology from space, types of meteorological satellites – Geostationary and Polar orbiting.

Unit II

International satellite systems and their payloads – NOAA, S-NPP, TERRA and AQUA, DMSP, METEOSAT, GOES, TRMM, etc., National satellite systems and their payloads – INSAT, IRS/RESOURCESAT, MEGHA-TROPIQUES, RISAT, OCEANSAT, etc., Agromet parameter's requirements and satellite data products available.

Unit III

Retrieval of cloud type and structure in visible and infrared regions, estimation of rainfall by visible, infrared and passive and active microwave techniques.

Unit IV

Retrieval of land surface emissivity and temperature – single channel and split window algorithms, components of surface radiation balance – global radiation, surface albedo and outgoing long wave radiation, estimation of latent heat flux (ET), sensible heat and roughness parameter.

Unit V

Retrieval of surface soil moisture by thermal and passive microwave, retrieval of crop biophysical parameters by empirical and physical techniques.

Unit VI

Vegetation phenology and dynamics, crop yield modelling, linking Simulation models and remote sensing, crop growth monitoring system

Unit VII

Drought monitoring, assessment and management, modelling net primary productivity of agroecosystems, agroecological zoning using remote sensing and GIS, remote sensing of air pollutants and greenhouse gases.

VI. **Practical**

- Handling MODIS image products (Reflectance, LAI, fAPAR, LST);
- Handling SPOT VGT Products, PROSAIL MODEL, Retrieval of: LST, Albedo, Radiation, Estimation of Crop Phenology from multi-temporal satellite images, Spectral yield model, Remote sensing-based Drought indices and Drought assessment and Spatial Net Primary Productivity modelling.

VII. **Teaching methods/activities**

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on satellite remote sensing in meteorology.

IX. Suggested Reading

- Lecture Notes Module II: *RS & GIS Applications in Agriculture & Soil Science*, CCSTEAP, Indian Institute of Remote Sensing, Dehradun, India
- Lecture Notes on *Satellite Meteorology & Global Change*, Vol 1, 2 & 3, CSSTEAP, Space Applications Centre, ISRO, Ahmedabad, India
- Molly E. Brown. 2008. *Famine Early Warning Systems and Remote Sensing Data*, Springer. Okamoto K. (Ed.). 2001. *Global Environment Remote Sensing*, IOS Press.
- Shivkumar MVK, Roy PS, Harmsen K and Saha SK. 2004. *Satellite Remote Sensing and GIS Applications in Agricultural Meteorology*, WMO, Geneva.
- Special Issue on Remote Sensing Applications in Meteorology, *Mausam*, Vol 54, No. 1, Jan 2003. Toselli F. (Ed.). 1989. *Applications of Remote Sensing to Agrometeorology*, Kluwer Academic Publishers, London.
- Ustin S. 2004. *Remote Sensing for Natural Resource Management and Environmental Monitoring*, 3rd ed., Wiley.
- Vaughan RA. 1987. *Remote Sensing Applications in Meteorology and Climatology*, NATO Science Series C.

I. Course Title : Sensors for Soil, Crop and Environment monitoring

II. Course Code : AP 606

III. Credit Hours : 2+1

IV. Aim of the course

To teach the applications of sensors for soil, crop and environment monitoring

V. Theory

Unit I

Sensing strategies: Traditional field scouting and sampling –laborious and time consuming, Sampling approaches.

Unit II

Sensor platforms and location of sensors: Remote airborne - Satellite, Airplane, UAV (1 m to 100 m); Proximal mobile, earthbound: Continuous moving, Stop - and - go, Proximal & in - situ, stationary Towers Probes in soil and on crop.

Unit III

Criteria for selecting sensors: Spatial sampling: Extend, coverage, sample area/volume Temporal: Turnaround time, temporal resolution Data processing: post processing / real - time Use in management: Predictive / reactive approach Costs Robustness Accuracy Handling: User - friendliness and safety, off - line, on-line, and on-line with map overlay.

Unit IV

Sensors for Environmental Monitoring: 1 Weather radar, 2 Satellite, 3 Aircraft, 4 UAV, 5 Atmospheric, Lidar, 6 Sensor network, 7 Radiometer, 8 Deposition sampler, 9 Atmospheric profiler, 10 Weather station & eddy - covariance 11 Groundwater level monitor, 12 Surface water level monitor, 13 Automatic water sampler, 14 Gas exchange sensor.

Unit V

Soil sensors: Plant nutrients (pools): Macro and Micro nutrients, Water content and water potential, Acidity (pH), Buffering, CEC, AEC, Redox Potential, Toxic substances like U, Cd, Pb, Physical properties: Soil strength, Permeability, Porosity Soil biota: Biological activity, pathogens, Organic matter, penetrometers, Geo-electrical sensors, Gamma ray soil sensing, potentiometric sensors, sensors for soil mapping, multi sensors, Visible and near - infrared diffuse reflectance spectroscopy (Vis - NIRS), sensor fusion, handheld XRF.

Unit VI

Plant sensors: Target parameters: Water Potential, Yield quality, Nutrients- macro and micro, Morphology: Biomass, Leaf area, Distribution of plants and organs, Biological threats: disease, pest and weeds, Principles of measurement: (a) mechanical, (b) optical (spectral, spatial resolution, geometry) (c) Acoustics.

Unit VII

Applications in agriculture: Principle of N application based on chlorophyll sensing with spot sensors, On - line application with map - overlay, weedSeeker, CropCircle & OptRXWEEDit Ag, CropSpec, Fluorescence sensor for agriculture, Laser: Crop morphology - leaf area, Imaging and Non-imaging crop sensors, site specific weed management, hyperspectral video cameras, 3D imaging, stereo vision, sensor based VRT, Thermal imaging, multi reflection ultra-sonic sensor, smart phone based sensors.

Unit VIII

Challenges of sensor technology in agriculture: Direct assessment of relevant properties/ better distinction between various factors, Robustness & user - friendliness, Costs, Data processing and interpretation.

VI. Practical

- Demonstration of various soil sensors, moisture pH, EC monitoring systems, crop sensors - Green seeker, SPAD meters, Leaf area meters, line quantum sensors, sensors for environment monitoring - humidity, temperature, radiation recorders, comparison of different sensors, optical, mechanical.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on sensors for soil, crop and environment monitoring.

IX. Suggested Reading

- Raphael A. Viscarra Rossel, Alex B. McBratney and Budiman Minasny. 2010. *Proximal Soil Sensing*. Springer Netherlands. ISBN 904818858X, 9789048188581, 448 pages.
- Subhas Chandra Mukhopadhyay. 2012. *Smart Sensing Technology for Agriculture and Environmental Monitoring*. Springer. 486 pages.
- Vanden Berg E. 2011. *Agricultural sensors*. ASAE publication. ISBN: 0916150984, 9780916150983, 81 pages.

I. Course Title : Weather Hazards and its Management

II. Course Code : AP 607

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge about natural hazards, their management and best practices

V. Theory

Unit I

Importance & scope of subject in the context of agriculture and developing countries; Concepts, definitions & fundamentals of Hazard, Disaster, Vulnerability, Resilience and Risk

Unit II

Classification of hazards: Natural & Human Induced, Geological – Hydrometeorological – Environmental – Biological, Sudden & creeping, Global and regional trends in hazards; Cycle and Steps in Disaster Management: Risk Management vs crisis management, Activities before, during and after disasters

Unit III

International treaties and mechanisms of disaster management, National institutional mechanisms

Unit IV

Early Warning and Communication system: Characteristics and Components of Early Warning System (formulation, issuance, reception and response), Disaster Specific National and International Early Warning Systems (Drought, Flood, Cyclone, Tsunami), Types of Communication Networks for Disaster Management (Terrestrial, Satellite, Wireless, Mobile), National Disaster Communication System

Unit V

Natural Disasters (Drought, Flood, Cyclone, Heat Wave / Cold Wave): their preparedness, Early warning & dissemination, response, recovery, mitigation

Unit VI

Biological Disasters (Epidemics, Pest attack of crops and livestock): their preparedness, Early warning & dissemination, response, recovery, mitigation

Unit VII

Risk Transfer and Insurance; Climate Change & Disaster Management

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Basic knowledge on natural hazards, their management and best practices

VIII. Suggested Reading

Books

- *Disaster Management in India*, Ministry of Home Affairs, Govt. of India, 2011.
- *Manual of Drought Management*, Ministry of Agriculture, Govt. of India, 2016.
- *Textbook of Disaster Management*, by Nitesh Kumar, Satish Serial Publishing House.

Journals

- *Natural Hazards*
- *Disasters*
- *Agriculture and Forest Meteorology*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Organic Farming

Preamble

Although, India had been traditionally organic and its farmers are 40 century farmers with large pool of traditional wisdom on best practices in organic agriculture, the modern standards based organic agriculture started only recently with the growing demand for organic food and fiber in the western world. Movement got major push when civil society organizations and farmer association brought in the focus on sustainability and food safety in the wake of deteriorating soil health and fertility, depleting natural resources, diminishing returns to the farmers and growing chemical residues in food. Growing demand for organic food nationally and internationally with the increased awareness for safe and healthy food further added to the strength of organic farming and attracted the attention of agricultural scientists and planners to look for alternative environment friendly ways which are not only productive enough to meet our growing demands but are also resource conserving and continuously contributing to the improvement of soil health and fertility. Organic agriculture emerged as the viable alternative to all such concerns. Ardent promoters of organic farming consider that present day organic agriculture, which is a mix of traditional wisdom and modern science and technology, can meet all these demands and become the mean for complete development of rural areas, especially in the developing countries like India where large chunk of farmers are small, with limited resources and with limited access to water, mainly through seasonal rains.

Institutional development such as National Programme for Organic production (NPOP) launched during 2001, followed by setting up of National Centre of Organic Farming (NCOF) under Ministry of Agriculture and Farmers Welfare and initiation of Network Project on Organic Farming (NPOF) Research by ICAR during 2004 laid the foundation for systematic development of the sector in the country. Started with just 42,000 ha during 2003-04, it has now grown almost 39-fold, touching a figure of 1.64 million ha during 2017-18. India is now the ninth largest in terms of total arable land under organic farming and largest in terms of total number of organic producers. Market started with exports is also catching up domestically and is now a 5000 crore industry. Dedicated stores and retail chains catering to the demand of organic food can be seen in almost all tier I and tier II cities in the country.

But this growth story has also many shortcomings and weaknesses. In the absence of technology and continuous research support, farmers are struggling to maintain yields. Availability of organic seeds and quality inputs for nutrient and pest management is one of the major bottlenecks. Absence of knowledge for diversified cropping systems (a pre-requisite for organic farming) keeps farmers relying on mono-crops which often yields poorly. Absence of trained manpower for extension, certification management and value chain management is also widely experienced and industry make do with less competent experts and personals. To take the organic farming fast forward it is necessary that efforts are made in value chain mode with an aim to transform farmers into entrepreneurs and create an infrastructure that cater to the ever evolving technology needs through research, extension and education. Although a National Organic Farming Research Institute (NOFRI) at Sikkim and some Institutes of Organic Farming in SAUs has started functioning but still there is lacking of institutions that can cater to the need of trained manpower. ICARs proposal to launch postgraduate programme in organic farming is the first of the efforts to bridge that gap. This report summarizes the recommendations of the committee constituted by the ICAR for drafting the course curriculum for M.Sc. Agriculture in Organic farming:

By the end of March 2017, India has brought more than 3.42 million ha area under organic certification, comprising of 1.64 million ha (47.95%) under cultivation and 1.780 million ha (52.05%) under wild harvest collection. India is producing wide range of crops under organic management with oilseeds, sugar crops, fiber crops, cereals and millets and pulses occupy the large chunk of the basket.

With mainstreaming of organic farming there is growing requirement for first generation extension personals trained in organic farming. Similarly, for research the country requires first generation scientists with actual organic farming background and passionate-will to work for the sector. As on March 2018 there are more than 3500 grower groups comprising of about 1 million farmers. These groups are known as ICS units and each group comprising of an average of 250-350 farmers and are managed by not less than 5-7 technical persons for documentation management, internal inspections, certification, collective input purchases and sales. Besides third-party certification another farmer group centric certification under PGS-India programme is also certifying farmers. To manage the certification of PGS there are more than 400 Regional Councils and all these require technical manpower, not only in organic crop and livestock management, but also in certification and quality assurance. As on March 2018, there are 28 certification bodies and another 10 are in the pipeline. Each certification body requires an average of 20-150 technical persons. Similarly, for PGS management there are more than 400 Regional Councils requiring more than 4000 technical staff. There are more than 950 organic food processors in the country. As organic system requires complete integrity, therefore processing needs to be dedicated, away from conventional processing units. This is a fast-growing sector and may require large number of organic food professionals in the years to come.Therefore, to feed to the existing and future requirement of technical manpower it is essential that a postgraduate course in organic farming is launched and state Agricultural Universities be encouraged to offer such course.

Minimum Requirements for starting postgraduate course in the University:

1. **Faculty**

University having Centre of Excellence in Organic farming or having dedicated Institutes for Organic farming are ideal for launching such programme. In cases, if there is no such existing infrastructure then the university must aim to start such Department with multidisciplinary faculty or must be in a position to spare competent faculty for undertaking such course. Initially it may be possible that the institute do not have faculty for each subject, then in such cases faculty may be contracted as visiting faculty for specific course content.

2. **Land**

As organic farming is a farming system approach, therefore, there is a needfor a dedicated organic farmof not less than 5 ha. This farm must be kept organic for long term as frequent switching of land under conventional and organic is not allowed and may not be advisable.

3. **Laboratory**

There must be fully equipped laboratory for the following:

(i) Soil testing laboratory having facilities for micronutrient analysis along with the usual soil test parameters. Facilities should also be available for estimation of soil microbial carbon, soil enzymatic analysis and soil respiration studies.

(ii) General microbiological laboratory

(iii) General entomology and plant pathology laboratory

(iv) Access to plant analysis equipment and residue analysis laboratories.

Course Title with Credit Load
M.Sc. (Ag) in Organic Farming

Course Code.	Course Title	Credit Hours
OF 501	Concepts and Principles of organic farming	2+0
OF 502	Soil fertility, Crop Nutrition and Nutrients input	3+1
OF 503	Organic Crop Production Systems	2+1
OF 504	Plant Health Management	2+1
OF 505	Post harvest handling of organic produce	1+1
OF 506	Farming systems suitable for organic managements	2+1
OF 507	Organic certification Standards and regulation	2+1
OF 508	Value Chain Management	2+2
OF 509	Marketing	2+0
OF 510	Research Methodology and Biostatistics	2+1
OF 511	Organic Input Management and Production Technologies	2+1
Soil 591	Masters Seminar	1+0
Soil 599	Masters Research/ Thesis	0+30

Course Contents
M.Sc. (Ag) in Organic Farming

I. Course Title : Concepts and Principles of Organic Farming
II. Course Code : OF 501
III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge on the basic concept of organic farming

V. Theory

Unit I: Concepts and principles of organic farming

History and evolution of organic farming in the world and India. Scenario of organic farming in India and world, global market for organic products, IFOAM's Guiding principles of organic farming, conversion to organic agriculture, advantages and limitations.

Unit II: Definitions and types of organic farming

Definitions of organic farming, types of organic farming such as natural farming, zero chemical natural farming, bio dynamic farming, biological farming, compost farming, Natueco culture, integrated farming, homa farming, permaculture etc, traditional farming systems in India and evolving indigenous knowledge systems

Unit III: Conventional *vs* Organic farming

Philosophy of two farming systems, fundamental differences, productivity issues, management protocols, food quality, nutritional differences and impact of conventional practices on soil fertility, natural resources, environment and overall social perception. Myths and realities about organic farming in addressing nutritional security and food safety need *vis-à-vis* national food security.

Unit IV: Advocacy, Ethics, health and social issues in organic farming

Advocacy for organic farming with sustainability, resource conservation and food safety issues. Advocacy through overall farm productivity under diversified cropping systems. Spirituality values and ethics in organic farming. Socio economic importance of organic farming: concept measurements and issues. Need for ethical practices and values across the organic agriculture value chain including trading and reaching to consumers.

Unit V: Organic farming for sustainability, resource conservation, climate change issues and safe and healthy food

General concerns on sustainability, climate change issues threatening sustainability, potential of organic farming practices in addressing sustainability and climate change. Resource conservation through organic farming, rainwater conservation and preservation of native seeds and germplasm an essential component of organic farming, Consumers concerns on food quality and safety, organic farming for safe and healthy food, ITKs potential and role in sustainability of modern organic farming practices

Teaching methods/ activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

Learning outcome

Basic knowledge on organic farming so as to be an organic trainer, promoter and grower.

Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition.
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Published by Jain Brothers
- *Basics of Organic Farming:* Deshpande, WR, 2009, All India Biodynamic and Organic Farming Association, Indore, MP, India P-306.
- Eyhorn, F, Heeb M and Weidmann, Gilles IFOAM *Training Manual for Organic Agriculture in the Tropics*, FiBL and IFOAM.

I. Course Title : Soil Fertility, Crop Nutrition and Nutrient Inputs

II. Course Code : OF 502

III. Credit Hours : 3+1

IV. Aim of the course

To provide knowledge on fertility of soil and also different organic inputs to be used in organic farming

V. Theory

Unit I: Soil – Source of Infinite Life

Soil as source of life, fundamentals of soil structure and quality, soil fertility, physico-chemical parameters and soil as living entity in organic farming.

Unit II: Soil fertility and productivity

History of soil fertility and plant nutrition. Factors affecting; features of good management; problems of supply and availability of nutrients; relation between nutrient supply and crop growth; Criteria of essentiality of nutrients; Essential plant nutrients – their functions, nutrient deficiency symptoms; transformation and dynamics of major plant nutrients.

Unit III: Soil fertility evaluation

Physico-chemical soil testing, biological methods for soil health evaluation, plant and tissue tests; soil quality in relation to sustainable agriculture. Nutrient requirement modeling based on soil health and resources availability.

Unit IV: Soil Conservation and Soil Water Management

Principles of soil and water conservation, general practices for soil and water conservation, soil carbon buildup and biomass recycling.

Unit V: Soil biology and role of microorganisms in soil fertility management

Soil as a habitat for microorganisms, Soil microorganisms, Soil microbial ecology, Soil microbial biomass, Soil enzymes – origin, activity and importance. Microbial management of agricultural, domestic and industrial wastes for potential application in organic farming. Microbiology of composting and bio-methanation. Biodegradation of xenobiotics. Bioremediation – principles and application.

Unit VI: Nutrient recycling

Nitrogen, phosphorus and potash cycles, management for nutrient recycling, methods for recycling and reducing nutrient losses.

Unit VII: Management practices

Management practices in organic agriculture (mulching, fallowing, intercropping, manuring, crop rotation, agro-forestry, mixed farming).

Unit VIII: Organic fertilizers and composting technology

Compositing principles and factors affecting composting, dynamics of compositing, methods of composting, different forms of composts with nutrient profiles, Rapid methods of composting, liquid manures, compost enrichment through concentrates, minerals and micronutrients. Field application of compost and their response to crops.

Unit IX: Vermicomposting technology

Earthworm biology, principles of vermicomposting, methods for vermicompost production, nutrient profiling, field application and its response to crop yields

Unit X: Biofertilizers

Different types of biofertilizers, their contribution to soil fertility and nutrient pool, factors affecting their application and response, assessment of biofertilizers application to crop yields.

Unit XI: Addressing nutrient deficiencies and mineral fortification of composts (P, K, S and micro nutrients)

Identification of deficiency, need assessment, identification of mineral resource, fortification of composts and impact assessment on application

Unit XII: Indigenous practices in soil fertility and nutrient management

Indigenous inputs such as liquid manures, Jivamrit, Panchgavya, on-farm protein hydrolysates, plant extracts, dung-urine slurries etc, their production methods and effect of their application on soil fertility and crop productivity.

VI. Practical

- Introduction of analytical instruments and their principles, calibration and applications, Determination of soil pH, electrical conductivity, organic carbon, total and available nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and DTPA extractable micronutrients in soil and their interpretations.
- Biological health assessment through dehydrogenases, soil microbial carbon and soil respiration
- Making of composts through aerobic and anaerobic methods
- Making of vermicomost using earthworms
- Analysis of manures and composts for NPK and heavy metals
- Microbial profiling of Jivamrit/ panchgavya

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on soil fertility and management in organic farming

IX. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Jain Brothers
- *Manufacture of Biofertilizer and Organic Farming.* AB publisher

I. Course Title : Organic Crop Production systems

II. Course Code : OF 503

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on organic crop production system

V. Theory

Unit I: Fundamentals of organic farm management and conversion

Salient features of organic farm management, strategies for conversion to organic, step-by-step planning, integration of contamination control measures, planning for on-farm input production and supplementary off-farm inputs, planning for rain water harvesting and water conservation approaches including efficient irrigation systems and moisture preservation techniques, visit to organic farms and study on farmer's best practices for conversion.

Unit II: Management of diversity and cropping systems

Importance of diversity, installation of diversity through plantation of utility trees, nitrogen fixing tree hedges, habitat management for friendly insects and birds and nitrogen fixing crops as intercrops. Importance of cropping systems management with long term planning, crop rotations, intercropping, multi cropping, relay cropping, multi-layered cropping.

Unit III: Nutrient management

Components of nutrient management in organic crop production, assessment of crop nutrient requirements, calculation of nutrient credits from on-farm practices and resources such as intercrops, cover crops, biomass mulching, calculating additional input requirements. Managing nutrient needs through use of organic manures, viz. FYM, compost, Vermicompost, oil cakes, *in-situ* and *ex-situ* green manuring, crop residue management, use of restricted organic nutrient sources, liquid organic manures and dung urine slurries, methods of manuring and biomass application, split application of manures, foliar feeding as replacement of top dressing, ITKs and farmers innovations in nutrient management

Unit IV: Integration of microbial and mineral inputs

Importance of bio fertilizers, types of biofertilizers, nutrient potential, methods of application, enriching manures/ composts with biofertilizers, identifying the need for use of supplementary mineral sources and their integration in nutrient management package.

Unit V: Weed management

Prevention of weeds through cropping systems management, crop geometry, stale seedbed technique, summer ploughing, soil solarisation, cover crops, mulching, flooding, biological weed management, selection of suitable physical and mechanical approaches and biological and plastic mulches.

Unit VI: Water and Irrigation Management

Soil-water relation, theories of water availability, water use efficiency management, methods of irrigation and automation in irrigation systems, irrigation scheduling in different crops.

Unit VII: Modeling of agronomic practices and nutrient management protocols for some important agricultural and horticultural crops

Identification of compatible associate and intercrops/ companion crops, placing trap crops and insectary plants in cropping geometry, making provisions for nutrient credits from biomass mulching, intercrops and green manures, making provisions for nutrient credits from microbial enrichment with microbial/ liquid manure inputs, balance nutrient requirement modeling and identification of inputs and planning for quantity and time of application.

Unit VIII: Crop growth and yield analysis

Crop growth expressions in plants, growth measurements, important growth indices and forms of growth analysis in field crops. Factors determining yield. Use of growth analysis technique to study variation in yield due to planting season, planting density, fertilizer treatment, other agronomic practices, light, temperature, water, growth substances, varietal differences. Crop response curves. Dynamics of crop growth and modeling.

Unit IX: Success stories of effective crop management with optimum yields of practicing organic farmers (one in irrigated systems and one in rainfed systems)

Field visit, documentation of farming system with inputs and outputs, identification of practices important for organic systems, nutrient management practices, pest management protocols, yields and economics. Salient features for success and for further replication in crop production modeling.

VI. Practical

- Visit to organic farms and study general nutrient management practices, documentation of farming system with inputs and outputs and crop growth analysis using crop growth analysis techniques
- Getting acquainted with different tilling methods and rain water harvesting and water conservation techniques
- Production of liquid manures and dung-urine slurries
- Production of customized composts using FYM/ Compost, mineral nutrients and biofertilizers, assessment of nutrient profiles in enriched composts
- Methods of application for biofertilizers
- Weed management practices, tools and efficacy of different approaches
- Modelling of agronomic practices for a given cropping system with use of available resources.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on organic crop production system

IX. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers.

I. Course Title : Plant Health Management

II. Course Code : OF 504

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on plant health management for optimization of crop yield due to organic farming

V. Theory

Unit I: Classification of pest organisms

Classification of pests, viz. weeds, bacteria, nematodes, fungi, insects, viruses, vertebrates, *etc*, identification of pests and beneficial organisms.

Unit II: General principles of plant health management in organic farming

Principles of pest management in organic crop production; Pest surveillance and pest population estimation; concept of economic injury levels (EILs) and economic threshold levels (ETLs), principles of Agro Eco-System Analysis (AESA) based pest management, estimation of Pest: Defender (P: D) ratio, understanding AESA methodology.

Unit III: Biology of pests and population dynamics

Population dynamics in relation to environment, distribution, identification; Life cycle of key pests of cereals, pulses, vegetables, stored grains, fruit crops and protected cultivation.

Unit IV: Ecological strategies for pest management

Proper sanitation, appropriate fertilization, necessary pruning, timing of planting to escape infection, crop rotation, avoidance of endemic sites, space management for sunlight and air, plant quarantine, *etc.*

Unit V: Cultural and physical control strategies

Importance and use of traps, coloured plates, pheromones, use of insectary plants, trap crops and planning for diversity plant integration as border crops, hedge rows, intercrops, *etc.*

Unit VI: Biological control

Conservation of natural enemies, classical biological control systems, important beneficial insects and their integration and use in different cropping systems.

Unit VII: Biopesticides

Biopesticides, types, mode of action, production, methods of application and impact assessment on crops and pest load.

Unit VIII: Botanical pest management

Using different plants for management of different pests, methods for using such plants and active ingredient extraction methodologies, formulation of usable solutions and methodologies for application. Integrated strategies, development of crop specific integrated management modules, importance and need for chemical alternatives permitted in organic farming, methods for use and application.

Unit IX: Indigenous practices and their importance in plant protection

Indigenous practices of avoiding pests, managing pests, important plants being used since ages and innovative botanical and fermentation inputs developed by farmers for pest management.

Unit X: Pest control of produce in storage

Physical, mechanical and biological approaches, modified environment, management of hygiene and phyto-sanitary approaches, use of organically acceptable fumigants such as carbon dioxide and nitrogen.

VI. Practical

- Collection and Identification of major/ key pests and plant diseases,
- Estimation of pest population, nature of damage, assessment of crop losses,
- Familiarization with important crop pests & diseases and their biological control agents,
- Demonstration/ familiarization with various tools of insect-pest & disease management,
- Mass rearing techniques of important biological control agents,
- Preparation of organic/ natural formulations for insect-pest & disease management,
- Evaluation of organic formulations for determining their pesticidal properties and field efficacy.
- Preparation and validation of traditional formulations.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Plant health will be taken care of for optimization of higher crop yield due to organic farming

IX. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher

I. Course Title : Post Harvest-handling of Organic Produce

II. Course Code : OF 505

III. Credit Hours : 1+1

IV. Aim of the course

To provide knowledge on post harvest handling of organic produce for optimization of crop yield due to organic farming

V. Theory

Unit I: Pre/Postharvest Factors for Post-harvest Losses of Organic Produce

Pre and post-harvest factors responsible for causing organic produce losses.

Principles and practices responsible for losses of organic agricultural produce. Qualitative, quantitative, nutritional and socioeconomic losses. Loss assessment and estimation techniques and their limitations and methods for reducing postharvest losses.

Unit II: Introduction to Value Chain and Handling of Fresh Organic Products for Processing

Management of hygiene and phyto-sanitary measures, measures to reduce field heat, cleaning and washing, control of enzymatic and non-enzymatic changes, transportation, sorting, grading, peeling, sampling and size reduction, packaging, labelling; handling methods for fresh fruits, vegetables and flowers.

Unit III: Organic Food Processing and Preservation

Fundamental principles for food processing in organic farming, acceptable processing techniques, use of preservatives, processing aids, flavouring agents and nutrient supplement in organic food and feed processing.

Unit IV: Food Standards and Residue Analysis/ Toxicology

Fundamental principles of food standards, HACCP system, US and European Export/ Import standards for different crops, MRLs, sources of contamination, assessment and management of residues and toxins in food, critical control points, heavy metals and pesticide residue analysis, analytical methods and tools. Interpretation of residue analysis reports, analysis protocols and GMO report analysis.

Unit V: Principles of Packaging

Characteristics of packaging materials for organic food, packaging requirements for fresh and processed organic food for local and international markets, labelling requirements for fresh and processed organic food for local and international markets, labelling requirements and management integrity.

VI. Practicals

- Study of maturity indices for harvest of organic fruits, vegetables, spices and plantation crops.
- Determination of physiological loss in weight and respiration rate in fruits and vegetables.
- Determination of chemical constituents like sugar, starch, pigments, vitamin C, carotenes, acidity during maturation and ripening in fruits/ vegetables.
- Protective skin coating with organic wax emulsion to extend the shelf life of fruits and vegetables.
- Study of effect of precooling on shelf-life and quality of fresh fruits, vegetables and flowers.
- Study of packages-bulk and consumer packs for different fruits, vegetables, flowers and spices.
- Study of construction and working of zero energy cool chamber. Study of storage behaviour of different fruits and vegetables in zero energy cool chamber.
- Preparation and preservation of fruit-based beverages and blended products from fruits and vegetables.
- HACCP analysis, residue analysis in organic products. Visit to packaging centres, local markets, cooperative organisations, super markets dealing with marketing of organic perishables.

VII. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers.

I. Course Title : Farming Systems Concepts and Practices for Organic Farming

II. Course Code : OF 506

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on practices of organic farming

V. Theory

Unit I: Introduction

Farming systems: Definition, importance, classification and scope, Classification of farming systems according to type of rotation, intensity of rotation, degree of commercialization, water supply, enterprises, Concept of sustainability in farming systems, role of integrated farming systems in agriculture, approaches

Unit II: Agro-ecology

Concepts and practices, Agro-ecology and the design of Sustainable Agro-ecosystems, Ecological processes to optimize in agro-ecosystems, Sustainable Agriculture: Basic Definitions and Concepts, Alternative Sustainable Farming Systems, Low external input sustainable agriculture

Unit III: Enterprises selection and Integration

Natural Farming Systems, Intentional Integrated Farming Systems, Pre-dominant farming systems in various regions, Eco-physiological approaches component selection and integration, Complementary and competitive interaction, Primary, Secondary, Complimentary and Supplementary enterprises for organic farming, livestock based systems, vertical farming, Principles and Practices of organic livestock production, Principles of organic aquaculture, Organic fruit and vegetable production practices, Models of integrated farming systems for irrigated ecosystems and rainfed ecosystems

Unit IV: Modeling of farming systems

Simulation models for intercropping, farming system design using farm design for various resource conditions, Linear programming, Multi-objective criteria decision making, Fuzzy logic analysis, Artificial Neural Network (ANN) based modeling, DSSAT, Infocrop, Cropsyst, Livesim

Unit V: Integrated Organic Farming Systems

Concepts, Principles, Strategies, Diversity plantations, Diversified cropping systems, crop rotations, soil fertility management, Selection of seeds, varieties and planting material, nutrient management, weed and pest management, integration of livestock, breeds and allied activities, *In-situ* recycling of Organic Wastes, Products and processes of composting, Component optimization, Market input chain, family employment generation, case studies, supplementary, Complimentary and substitution effects under dry-land, irrigated, wetland and hill-zone eco systems

Unit VI: Soil-crop-livestock-human chain

Bio-nutrition concepts, design of farming systems for nutrition, Household level production of food, feed, fodder, fertilizer, fuel and fibre from farming systems

Unit VII: Secondary Agriculture

Product diversification, Process diversification, processing of marketable surplus produces, packaging, branding and marketing

Unit VIII: Contract Farming

Farming system based cluster formation, production, processing and marketing, legal aspects of contract farming

Unit IX: Specialized farming systems

Protected cultivation, high value crops based systems, water based farming systems, region specific integrated farming systems, medicinal herb based systems

Unit X: Farming System diversification

Existing scenario of farming systems, need for diversification, methods of diversification, horizontal and vertical diversification

Unit XI: Four P Model of organic farming system

4P (Planning, Production, Processing and Promotion) model of organic farming systems

Unit XII: Ecological Engineering

Principles and Practices, Ecological engineering approach of soil fertility and pest management, examples of ecological engineering in traditional farming systems, case studies

VI. Practical

- Agro-ecosystem analysis: Field study of farming systems in the context of production flows, energy flows and pest dynamics using quantitative tools
- Farming System typology analysis and clustering of group of farmers
- Synthesis of organic farming system model for a given region using primary and secondary data
- Estimation of ecological, economic, social and sustainable livelihood indicators for a given farming system
- Design of alternative farming systems using Farm Design and other available modelling tools
- Experiential learning on different enterprises
- Documentation of farming system case studies

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion
Learning outcome: leadership development for an organic entrepreneur

VIII. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Jain Brothers.
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. Course Title : Organic Certification, Standards and Regulations

II. Course Code : OF 507

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge Organic Certification, Standards and Regulations

V. Theory

Unit I

National and international regulations on quality assurance and certification

National Programme for Organic Production (NPOP), National Standards for Organic Production (NSOP), USDA NOP Programme and standards, EU Organic standards, Codex Alimentarius, Canada Organic regulation and important differences between NPOP and international standards. FSS Act 2006 for organic food, basic requirements, enforcement, standard operating procedures and verification in value chain

Unit II

ISO systems for quality assurance (ISO 17065, ISO 17011, ISO 19011 etc) and accreditation processes

What is ISO, salient features and functions of ISO, ISO systems for auditing, ISO 17065 for auditing and certification agencies, ISO 19011 Inspection protocols, ISO17011 Accreditation requirements, ISO 17025 Accreditation of quality analysis laboratories. Accreditation procedure and policies under NPOP, Essential requirements and competence for making an organic certification body, Conflict of interest management

Unit III

Types of certification systems (NPOP and PGS), standards and procedures

NPOP - A third party certification systems, Certification bodies operational policies and functions, National standards for crop production, livestock, Aquaculture, Processing and handling and other miscellaneous systems. Tracenet the online data management tool and traceability management

PGS – Participatory Guarantee Systems – Evolution of PGS Systems, Guiding principles, PGS Standards, International scenario on PGS development Procedure for organic guarantee under PGS systems, PGS-India programme, operation of PGS-India programme, institutional structure, PGS-India Data management platform, management of traceability.

Unit IV

On-field management of standard compliance and documentation

Issues for implementation of standards on field such as conversion period, contamination control, fertility management, living condition requirement for livestock, management of integrity in processing and handling, Fundamental policy for inspections, step-by-step inspection protocols, Development of inspection formats and inspection checklists. Documentation requirements such as organic system plan, field operation register, input and cultural practices record, processing record, purchase and sales records and product flow in processing.

Unit V

Individual and grower group certification management

Basic requirements for certification management by (a) Individual producer and (b) Grower/ producer groups. Applicability and types of systems covered

Unit VI

Inspection (under NPOP) and peer review (under PGS) systems

Fundamental principles of inspection, checklists and inspection parameters, general policy frame work

NPOP – Third party inspection procedure, risk assessment, documentation and record keeping review, physical verification of facilities, fields and stables, production facilities, estimated yield/production assessment, tracking the product flow throughout the process, chain of custody. Review of inspection forms and checklists and certification decisions.

PGS-India – Peer review principles, making of peer review committees and peer review checklists, analysis of peer review checklists and certification decisions. Submission of summary sheets to Regional councils and assessment and endorsement of certification decisions.

Unit VII

Certification of crop, livestock, aquaculture and other systems

Standards, their implementation in production systems, measures for contamination control, integrity management, sanitation and hygiene, input evaluation procedures, development of process tracking checklists

Unit VIII

Certification of processing, handling, trading and management of traceability

Standards, their implementation in production/ processing and handling systems, measures for contamination control, integrity management, sanitation and hygiene, packaging and labelling, development of process tracking checklists

Unit IX

Internal control system management in large farmer groupsunder NPOP

Large farmer groups, essential requirements, internal control systems, development of ICS operating manual, management of ICS, internal inspections, risk assessment, assessment of internal inspections and certification decisions, additional documentation for groups, produce/ output management and sale record management

Unit X

PGS Group development and PGS certification management

Essential requirements for local groups, development of local group operating manuals, requirements of group meetings and trainings, decision making by farmers, operational policies for Regional Councils, developing operating manual for Regional councils, assessment of summary sheets and decisions of local groups, procedure for decision endorsement and certification granting

VI. Practical

- Documentation of certification procedures, acquaintance with record keeping, handling, labeling and preparation of farmers IDs for developing ICS.
- Visit to certification bodies, certified farms, certified processing and handling operations
- Development of organic system plan for specific production system
- Development of inspection format and checklists for specific production system
- Development of operating procedures on specific aspects
- Risk assessment on organic farms and possible mitigating measures
- Running of audit trails in certified operations
- Mock inspections of different production systems
- Exercise on inspection report/ peer evaluation checklist review and certification decision
- Exercise on methods of yield assessment

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Educating to become a real organic grower

IX. Suggested Reading

- *Basics of Organic Farming:* Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Jain Brothers.
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. Course Title : Value Chain Management

II. Course Code : OF 508

III. Credit Hours : 2+2

IV. Aim of the course

To provide knowledge on value chain for optimization of crop yield due to organic farming

V. Theory

Unit I: Introduction

What is value chain? Defining value chain and its finance (Internal value chain finance, External value chain finance, Interest around value chain finance in agriculture, interest in value chain finance in agriculture); Overview of value chain management.

Unit II: Understanding agricultural value chain finance

Context, the concept of agricultural value chain finance, Agricultural value chain finance as an approach, Enabling environment (standards and certification, regulation and enforcement, macro-economic and social context), and Value chains and diversified livelihoods.

Unit III: Value chain business models

Producer-driven value chain models, Buyer-driven value chain models, Facilitated value chain models, and Integrated value chain models. Case Study 1. On commercial village approach.

Unit IV: Agricultural value chain finance instruments

Product overview, Product financing (trader credit, input supplier credit, marketing company credit, lead firm financing), Receivables financing (Trade receivables finance, factoring and forfeiting), Physical asset collateralization (warehouse receipts, repurchase agreements, financial lease), Risk mitigation products (crop/ weather insurance, forward contracting, futures), Financial enhancements (securitization, loan guarantees, joint ventures). Case Study 2. Producer-driven financing of farm inputs: informal inventory credit; Case Study 3. Integrated financial instruments and value chain services.

Unit V: Innovations

Value chain innovations, Financial innovations, Technological innovations (management systems, networks and exchanges, mobile phones and mobile banking), Infrastructural innovations, Policy and public sector innovations. Case Study 4. Technological innovations; Case Study 5. Avenues for sustainable agricultural development.

Unit VI: Leadership Approaches for Successful Food Value Chains

Values-Based Leadership, Values-Based Leadership in Practice, Leadership in succession.

Unit VII: Organic food value chain management

VI. Practicals

- Collection, aggregation and value addition
- Maintain quality and integrity of the product - practices and procedures, monitoring practices and procedures followed, record keeping systems, management practices and separation measures, handling and processing of organic products
- Pest control - Treatments with pest regulating agents – permitted [physical barriers, sound, ultra-sound, light and UV-light, traps (incl. pheromone traps and static bait traps), temperature control, controlled atmosphere and diatomaceousearth] and prohibited
- Ingredients - approved and prohibited ingredients (microorganisms, minerals, gases)
- Processingmethods - permitted and prohibited mechanical, physical and biological
- Packaging - permissible biodegradable, recyclable, reusable systems and eco-friendly packaging
- Labeling - labeling requirements for agricultural commodities and processed food
- Storage and Transport - permitted conditions of storage to maintain productintegrity
- Food additives including carriers for use in production of processed organic food
- Processing aids and other products for use for processing of ingredients of agricultural origin from organic production flavouring agents, Preparations of Micro-organisms, Ingredients
- Approved products for packaging of organic foodstuffs incl. Permissible packaging material for aquaculture

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

High value in organic products

IX. Suggested Reading

- *Basics of Organic Farming:* Mamta Bansal. Kindle Edition.
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers.
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. Course Title : Marketing

II. Course Code : OF 509

III. Credit Hours : 2+0

IV. Aim of the course

To provide knowledge on marketing of organic produce for economic profit of the grower

V. Theory

Unit I: What is Marketing?

Facets of marketing, Facilitating functions of a market, What's special about agricultural markets? Pricing policy and Role of prices.

Unit II: Basics of Supply and Demand–

Demand, Aggregate demand, Supply and Aggregate supply.

Unit III: Food Marketing Channel–

Understanding the food marketing channel, Scenario Analysis.

Unit IV: Market intelligence–

Marketresearch, Production cost assessment, Projecting Revenues, Accounting, Market Selection.

Unit V

Organic production and domestic market size, Institutional context and regulations (such as NPOP, NSOP, APGMC Act, PGS, FSSAI, Jaivik Bharat).

Unit VI: Organic Food Distribution System–

Domestic market structures, and classification framework, urban organic retail models, Organic specialty stores, markets and health food stores. Direct marketing and Community Supported Agriculture.

Unit VII: Market Potential for Organic Foods–

Consumer preferences and perceptions (organic sensitivity, building awareness on organic foods and consumer needs, shopping Behavior, factors influencing purchases of new foods), general trade and organized retail.

Unit VIII: e-Marketing and e-Consumer Perceptions and Behaviour–

Why organic food, source and perception of organic foods, uses of organic food, resistance to use organic products, source of awareness, organic food-is it a fad?, On-line retail and home delivery services, role of advertising and choice of media, understanding the role of quality in marketing, perception of health benefits and assurance/certification.

Unit IX

Accessibility of organic foods, premiums and willingness to pay premiums, role of retailer

Unit X

Efficient supply chains and retail channels, sustainability of supply chain.

Unit XI: Consumer purchase Behavior and habits–

Shopping Behavior, role of influencer in decision making, concern over adulteration, chemicals, loss of nutrients and vitamins during processing and manufacturing and its impact on marketing and sale.

Unit XII: Challenges and success stories–

Success stories in organic marketing, organizational models, their advantages, challenges, limitations and legal context.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VII. Learning outcome

Basic knowledge on marketing to get higher prices in organic produces.

VIII. Suggested Reading

- *Basics of Organic Farming:* Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. Course Title : Research Methodology and Biostatistics

II. Course Code : OF 510

III. Credit Hours : 2 + 1

IV. Theory

Unit I

Experimental techniques: Research design, sampling, data collection, On-station experimentation, On-Farm experimentation, tabulation, Statistical tools and analysis techniques for interpretation of data.

Unit II

Geo-referenced characterization: Questionnaire design principles, Questionnaire design for consumers of organic products, Questionnaire design for farmers and producers of organic products, Questionnaire design for processors/ traders/ exporters, Geo-spatial analysis and mapping of organic farms/ producers/ traders/ consumers.

Unit III

Meta data analysis: Concepts, statistical methods, clustering research results, Holism, Positivism, Objectivism, Reductionism, Constructivism, Subjectivism, data source, Variable coding and analysis, interpretation.

Unit IV

Niche area and crops for organic farming: Parameters for niche area and crop, Different scales of niche area, Tools and steps in Niche area and crop identification, Parameterization and classification based on macro, regional and micro level.

Unit V

Climate resilience of organic farming: Methodology for identification of climate resilient production systems, GHG's estimation using IPCC, GHG's measurement using instrumentation, Global Warming Potential, Energy & Carbon budgeting.

Unit VI

Breeding for organic production system: Conventional breeding strategies for organic production, participatory plant breeding, Marker aided selection, Stability analysis, Molecular characterization of indigenous organic inputs, Bio-chemical and molecular signature of organic produces.

Unit VII

Commercial Project Formulation on Organic Farming: Internal rate of return, Pay Back period, B: C ratio, Net Present Value, Model project formulation for organic farming, Impact analysis tools and methods.

Unit VIII

Farming System model development: Synthesis of IFS models using primary and secondary data, classification, validation of farming systems.

Unit IX

Notations in statistics: Basics of statistical notation, Algebric rules, designing a variable, standard notation for statistics.

Unit X

Descriptive statistics: Measures of central tendency, measures of variability, relative scores, measures of relationship, skewness, kurtosis.

Unit XI

Introduction to statistical inference and testing of hypothesis: Statistical model, point estimation, confidence intervals, hypothesis testing, t-test, non-parametric alternative sign test.

V. Practical

- Synthesis of farming system model
- Estimation of GHG emission from IPCC tool
- Meta data analysis using published papers
- Identification and niche area and crops for a district or block
- Identification of Climate resilient production system using long term meteorological data
- Commercial project formulation
- Geo-spatial analysis using GIS platform
- Carbon and energy budgeting of an organic farm

I. Course Title : Organic Input Management and Production Technologies

II. Course Code : OF 511

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on various organic inputs, their production technologies, quality control and commercialization aspects

V. Theory

Unit I: Introduction

Need for on-farm and off-farm (external) organic inputs, types of organic inputs allowed under organic farming, regulatory scenarios and standards. Status of organic and biological input industry in the country.

Unit II: On-farm inputs soil fertility and nutrient management

Types of on-farm inputs for soil fertility and nutrient management, their need assessment under specific cropping systems *vis-à-vis* soil test reports, methodologies for recycling of on-farm biomass and crop residue, innovative traditional inputs such as jivamrit, beejamrit, panchgavya etc. their microbial profiling and nutrient mobilization potential and standardized production methods, Oil cakes and their applications.

Unit III: On-farm inputs, plant health management and pest control

Types of plant protection inputs and intervention approaches, use of biological and ecological approaches, preventive practices, Types of plants used in plant protection and their biological characterization for pest control, basic methodologies for active ingredient extraction and on-farm formulations.

Unit IV: Composts and their value added products

Types of composts, their characters, nutrient potential, composting methodologies (aerobic, anaerobic, NADEP, *etc*), value added composts, quality control parameters, commercial production methodologies for city waste compost, Phosphate Rich Organic manure (PROM), bio-organic manure, technologies for product formulations such as enrichment and granulations, *etc.*

Unit V: Biofertilizers

Types of biofertilizers, standards for commercial products, testing methodologies, characterization and efficiency parameters, management of microorganisms in laboratory, production methodologies such as mother culture development, mass production through fermentation and fermentation parameters, mass scale culture techniques, product formulations, carrier-based inoculants, liquid inoculants and lyophilized inoculants.

Unit VI: Microbial Biopesticides

Types of biopesticides, standards for commercial products, testing methodologies, characterization and efficiency parameters, management of microorganisms in laboratory, production methodologies such as mother culture development, mass production through fermentation and fermentation parameters, mass scale culture techniques, product formulations, carrier based inoculants, liquid inoculants and lyophilized inoculants. Types of polyhedrosis and granulosis viruses and their production methodologies.

Unit VII: Mass rearing of beneficial insects

Introduction to beneficial insects such as pest predators and parasites, classification and identification, mass rearing technologies including rearing of host insects, Production of egg cards of beneficial insects and their release in the field.

Unit VIII: Botanical pesticides and other non-chemical pest protectants

Type of non-chemical plant protection options, importance of soaps and oils, important plants having pesticidal properties, plant parts having pesticidal active ingredient and their extraction methodologies, product formulation and stabilization for increased shelf life, field assessment of efficacy. Regulatory scenario and quality parameters.

VI. Practical

- Getting familiarized with on-farm soil fertility management inputs (such as beejamrit, jivamrit, panchgavyaetc), ingredients needed and production methodology. Preparation and quality assessment
- Application of such inputs in small plots on selected crops and observation on growth
- Production of different composts including vermicompost
- Quality analysis of composts for nutrients and heavy metals
- Biofertilizer organisms, their laboratory characterization, sub-culturing and mother culture development
- Fermentation technology demonstration, production of bacterial broth in pilot scale fermenters
- Biofertilizer product formulations and quality analysis methods
- Study biopesticide organisms, laboratory culturing, mass cultivation using solid state fermentation, liquid fermentation and spore harvesting methods and product formulations
- Visit to beneficial insect rearing laboratory and handling of insects including demonstration on tricho-cards production
- Extraction of neem seed kernel extracts and neem oil. Production of botanical extracts and product formulation using emulsifiers
- Study effect of various botanical extracts on insect pests
- Preparation of Bordeaux mixtures and copper fungicides

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion. Practical in the laboratory, visit to production sites and demonstration of production protocols through industry visits, practical on analysis protocols

VIII. Learning outcome

Basic knowledge on marketing to get higher prices in organic produces.

IX. Suggested Reading

- *The Complete Technology Book on Vermiculture and Vermicompost*, NPCS Board of consultants and Engineers, Asia Pacific Business Press
- *Training material on Composting and Vermicomposting*, Published by Ecosan Services Foundation
- *Biofertilizers and Biopesticides*, A, Channabasava and H.C. Lakshman
- *Handbook of Biofertilizers and Biopesticides*, by AM Deshmukh, RM Khobrgade and PP Dixit
- *Mass Production of Beneficial Organisms*, by J. Morales-Ramos, M. Guadalupe and DS Ilan, Academic Press, 2013.

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 2

Social Sciences

- Agricultural Economics
- Agricultural Extension Education
- Agri-Business Management

Contents

Acknowledgements

The disciplines of Social Sciences deal with the study of society and the relationship among individuals within society. It includes study of business, sociology, commerce, demography, and allied areas. Research in Social science research provides authentic and scientifically validated information to the end users. The importance of social research is reflected in its ability to provide fact-checked and well-validated answers to questions involving human interactions. Hence, while technology can serve the purpose of taking agricultural sciences across society for bettering profits and livelihoods and also become food and nutritional-secure, social science research can enhance the social unity by providing solutions at the doorstep of the end-users with a societal acceptance. It is most important that Agricultural Universities develop their curriculum integrating the technology developing sciences into the social sciences and catalyse trained social science professionals. Deployment of technologies-be it cost-intensive cutting-edge agricultural technologies or simple local innovations is crucial for augmenting agricultural production for our country and social science professionals have a crucial role to play in the dissemination to the end-users.

Against this responsibility to develop such trained professionals, this committee of BSMA has done 360 degree evaluation of the current curriculum of three disciplines namely, Agricultural Extension, Agricultural Economics and Agri-Business Management adopting a multi-pronged approach. Hence, stakeholder interaction, expert consultation and analysis of curriculum of global-level agricultural universities formed the basis to match the needs as per the national vision. Specifically, the committee has also explored the essence of National Educational Policy (NEP) into the curriculum planning processes. The Fifth Dean Committee report and the earlier under-graduate curricula in three disciplines also formed an important base for the committee to ensure continuity with UG and PG curriculum. We would like to put on record our sincere thanks to Dr T. Mohopatra, Secretary, DARE and Director General (DG), ICAR; Dr N.S. Rathore, Former Deputy Director General (Education), and Dr R.C. Agrawal, Deputy Director General (Education), ICAR, New Delhi for constituting this committee. We are highly indebted to Dr Arvind Kumar, Vice Chancellor, RLBCAU and Chairman of National Core Group for PG/ PHD course revision for his patience and constant support. The role of Dr G.Venkateshwarlu, Former ADG (EQR) as Member Secretary, NCG has been extremely supportive and crucial during the two years of this activity for this committee. The committee puts on record with appreciation his constant support to it.

Our sincere gratitude and thanks to all the members of this BSMA Committee for Social Sciences namely Dr Rakesh Singh , Professor, Dept. of Agricultural Economics, IAS, BHU, Varanasi, Dr S. Mahapatra, Professor and Head, Agri Business Management, OUAT, Bhubaneswar, and Dr Aditi Mathur, Professor, Institute of Agri Business Management, Swami Keshwanand Rajasthan Agricultural University, Bikaner for their continuous support, encouragement and suggestive nature throughout the journey of final draft preparation.

Lipi Das	**R.Kalpana Sastry**
Convenor	Chairperson
BSMA for Social Sciences	BSMA for Social Sciences

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Social Sciences
– Agricultural Economics

Acknowledgements

Agricultural sector plays an important role in Indian Economy. Changes in agricultural sector are taking place at a faster rate and this sector is integrated globally and therefore facing global challenges. In the era of Information and Communication Technology, the knowledge which we gain becomes obsolete within few years therefore it is important to update/ reform our curriculum in line with the recent changes taking place. The major challenges faced by agricultural sector currently is related to distribution/ supply chain rather than production side. We are largest producer of food grain, horticultural products milk and livestock products but we are the host of large no of poor people and mal nutrition people. Farmers' distress has become the major cause of concern for policy makers, on the other hand climate change is posing many challenges.

The sub-committee on Agricultural Economics constituted by ICAR (under the ICAR Broad Subject Matter Area (BSMA) for Social Sciences) has kept all these challenges and development in view while revising the PG and PhD Curricula in Agricultural Economics. We reviewed the under-graduate, PG and Ph.D curricula. Moreover, student's prior knowledge is critical for learning any discipline and so we had to review and propose a new curriculum for Agricultural Economics at all levels. To do these, we identified first the core competencies that are required at the different levels and worked backwards based on the areas and organising them into courses.

We are also recommending internship at the Master's level for 5 credits and Teaching Assistantship at the Ph.D. level for 5 credits. We believe this will help the students to have more relevant practical experience and this will boost their job prospects. The committee also discussed about the need for organizing exposure visit for PG/Ph.D. students to universities abroad (student exchange).

The committee organized three national level stakeholders meeting and consultation with Agril Economics professionals representing different universities, ICAR institutions involved in teaching and research in Agricultural Economics first at PJTSAU, Hyderabad on 12 July 2018, second meeting at Institute of Agri Business Management, Swami Keshwanand Rajasthan Agril University, Bikaner during September 17-18, 2018 and third BSMA (Social Sciences) meeting on 28-01-2019 at Institute of Agricultural Sciences, BHU, Varanasi for reviewing the final drafts of three disciplines of Social Sciences.

Our sincere thanks to Prof. Suhasini, Head, Dr (Mrs) Vijayakumari and faculty members, research scholars of Dept of Agril Economics, PJTSAU, Hyderabad; Prof. Smita Sirohi, Head Agril Economics, NDRI, Karnal (Haryana); Prof. RL Shiyani, Junagarh Agril. University Gujarat; Prof. Sanjay Kumar Srivastava, GBPUA&T, Pantanagar, Prof. Rajesh Sharma, HOD and Prof. Madhu Sharma, SKRAU Bikaner; Prof. PS Badal, Prof Chandra Sen, Prof. HP Singh, Dr O.P. Singh, Dr Prashant Kumar Singh, Dr Manish Kumar Yadav, Dr Neeraj Singh and research scholar ofrom the Department of Agril Economics, Institute of Agril Sciences BHU, Dr Ranjit HOD ABM, NAARM Hyderabad for their participation and valuable inputs/ suggestion in the development of course curriculum of Aril Economics. We extend our gratitude to Prof. Jyoti Kacharoo, HOD Agril Economics, SKUAST, Jammu; Prof. Wani, HOD, SKUAST, Srinagar, Prof. HN Singh, HOD, GBPUAT, Prof. Alka Singh, IARI, New Delhi, Prof. Ram Singh, HOD, CAU, Barapani, Prof. KK Datta, CAU, Barapani, Shillong for their critical inputs and suggestion. We thank to Prof. Rakesh Bhatnagar, Vice-Chancellor, BHU, Prof. Ramesh Chand, Director, Institute of Agril. Sciences, Prof. AP Singh, Dean, Prof. PS Badal, Head for their support to organize the BSMA meeting at BHU Varanasi.

Our sincere gratitude and thanks to all the members of BSMA Committee for Social Sciences, namely, Prof. I Sreenivasa Rao, Professor, Dept. of Extension, PJTSAU, Hyderabad; Dr S Mahapatra, Professor and Head, Agri Business Management, OUAT, Bhubaneswar, and Dr Aditi Mathur, Professor, Institute of Agri Business Management, Swami Keshwanand Rajasthan Agricultural University, Bikaner for their continuous support, encouragement and suggestive nature throughout the journey of final draft preparation.

Finally, we thank profusely Dr NS Rathore, Former Deputy Director General (Education), ICAR, New Delhi, Dr Venkateswarlu, Former ADG (EQR), ICAR for constituting the BSMA for undertaking curricula revision of PG and Ph.D. and their valuable guidance and support in this regard.

Prof. Rakesh Singh (Member, BSMA, Agricultural Economics)
Dr Lipi Das (Convener, BSMA, Social Sciences)
Dr Kalpana Sastry (Chairperson, BSMA, Social Sciences)

Course Title with Credit load
M.Sc. (Ag) in Agricultural Economics

Major Courses: 20 credits

Course Code	Course Title	Credit Hours
AEC-501*	Micro Economic Theory And Applications	3 (3+0)
AEC-502*	Agricultural Production Economics	2 (1+1)
AEC-503*	Agricultural Marketing and Price Analysis	3 (2+1)
AEC-504*	Macro Economics And Policy	2 (2+0)
AEC-505*	Econometrics	3 (2+1)
AEC- 506	Agricultural Development and Policy Analysis	2 (2+0)
AEC-507*	Agricultural Finance and Project Management	3 (2+1)
AEC-508*	Linear Programming	2 (1+1)
AEC-509*	Research Methodology for Social Sciences	2 (1+1)
AEC-510	Indian Economy: History and Contemporary Issues	2 (2+0)
AEC-511	International Economics	2 (1+1)

*courses to be taken compulsorily

Minor Courses: 08 credits

a. It is suggested the student may choose at least two out of three courses listed above as part of minor courses as these are related to policy advocacy and aim to build larger understanding of the subject.
b. Further, it is suggested that the student may also opt to choose the remaining Courses from any other discipline including the disciplines of Agrl. Extensions/ ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/ HOD.

Course Code	Course Title	Credit Hours
AEC-512	Institutional Economics	1(1+0)
AEC-513	Natural Resource and Environmental Economics	2 (1+1)
AEC-514	Commodity Future Trading	2 (2+0)
AEC-515	Development Economics	2 (2+0)
AEC-516	Rural Marketing	2 (2+0)
AEC-517	Evolution of Economic Thought	1 (1+0)

Minor courses may be taken from above list or subjects closely related to a student's major subject.

Supporting Courses: 6 credits

STAT-501	Statistical Methods For Applied/ Social Sciences	3 (2+1)
STAT-502	Mathematics For Applied Sciences/ Agricultural Economics	3 (2+1)
STAT/COMP	Computer Applications For Agri-Business & Economics	3 (2+1)

Common Courses: 05 credits

1. Technical Writing and Communications Skills
2. Intellectual Property and its management in Agriculture
3. Agricultural Research, Research Ethics and Rural Development Programmes

Further, the subcommittee attempted to oversee the design of the entire course is such a way that students may opt to take extra courses to compete with MA Economics stream and Universities may consider to issue a certificate that the degree of M.Sc.(Ag) Agricultural Economics with special mention of extra credits in core Economics.

Course Contents
M.Sc. (Ag) in Agricultural Economics

I. Course Title : Micro Economic Theory and Applications
II. Course Code : AEC-501
III. Credit Hours : 3+0

IV. Why this course?

Markets form an integral part of the economy. They are governed by demand and supply mechanism with profit making its ultimate goal. Thus, it is imperative to expose the students towards how the markets function, their types and how the buyers and sellers behave. That will help them make correct decision when it comes to price setting and choice of product.

V. Aim of the course

The course envisages the concepts and principles embodying micro-economics. The economic problems, functioning of price mechanism, theory of household behaviour and consumer's demand function. Theory of firm, supply determinants, determination of price under different market structures and factor pricing (micro economic components).

VI. Organisation of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to micro-economics	1. Basic Concepts: A review
2.	Insight of consumer, production and cost involved	1. Consumer Choice 2. Production and Cost
3.	Overview of market	1. Market Forms 2. Factor Markets

VII. Theory

Block 1: Introduction to micro-economics

Unit 1: Basic Concepts: A review

Scarcity and Choice; Production possibility frontier, Positive and normative economics; concepts of opportunity cost, Demand and Supply: determinants of individual demand/supply; demand/ supply schedule and demand/ supply curve; market versus individual demand/ supply; shifts in the demand/ supply curve

Block 2- Insight of consumer, production and cost involved

Unit 1: Consumer Choice

Cardinal Utility Approach – Ordinal Utility Approach -Budget sets and Preferences under different situations – Hicks and Slutsky income and substitution effects –

Applications of Indifference curve approach – Revealed Preference Hypothesis – Consumer surplus – Derivation of Demand curve – Elasticity of demand – Demand and supply together; how prices allocate resources; controls on prices – price floor and price ceiling – applications in agriculture.

Unit 2: Production and Cost

Production functions: single variable - average and marginal product, variable proportions, stages of production. Two variables - isoquants, returns to scale and to a factor; factor prices; Technical progress; cost minimization and output maximization; Elasticity of substitution. Expansion path and the cost function Concept of economic cost; Short run and long run cost curves; increasing and decreasing cost industries; envelope curve; L-shaped cost curves; economies of scale; revenue and expenditure, elasticity and marginal revenue; Firm equilibrium and profit.

Block 3: Overview of market

Unit 1: Market Forms

Behaviour of profit maximizing firms and the production process- Perfect competition: Equilibrium of the market. Long run industry supply, applications: effects of taxes and subsidies; Monopoly: Equilibrium; supply; multiplant firm; monopoly power; deadweight loss; price discrimination; Monopolistic Competition: Product differentiation; equilibrium of the firm in the industry-with entry of new firms and with price competition. Comparison with pure competition. Duoploy: Cournot model and reaction curves; Stackelberg's model, Bertrand model; Oligopoly.

Unit 2: Factor Markets

Labour and land markets - basic concepts (derived demand, productivity of an input, marginal productivity of labour, marginal revenue product); demand for labour; input demand curves; shifts in input demand curves; competitive labour markets; Economic rent and quasi rent.

VIII. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions on practises done by firms.
- Power point presentations by students.
- Exploring the agricultural market and identification of industries and their type.

IX. Learning outcome

After completion of the course the student will be able to:

- Get acquainted with the basic concepts of market functions.
- Build up vision towards how consumers makes choices and market reaches the equilibrium.
- Develop decision making skill for firms about product selections and scale of production to ensure maximum profit.
- Understand about different types of markets existing in the real world, their principles and whereabouts.

X. Suggested Reading

- Koutsoyiannis A. *Modern Micro Economics*. Macmillan Press Ltd

- Ferguson and Gould. *Micro Economic Theory*. Richard D Erwin Inc., USA
- Richard A. Bilas, *Micro Economic Theory*.
- Leftwich Richard H. *The Price System and Resources Allocation*
- Allen CL. *A Frame Work of Price Theory*.

I. Course Title : Agricultural Production Economics

II. Course Code : AEC-502

III. Credit Hours : 1+1

IV. Why this course?

Production in agriculture is the outcome of the input factors involved. In this competitive and uncertain market, it is important that the farmers take the right decision about the combination of inputs that will result in higher income. Thus, as an economist it is a pre-requisite that the students understand the interaction between output and input. And work out the most effective production plan.

V. Aim of the course

To expose the students to develop the concept, significance and uses of production economics. To understand the relationships between factors and output. To learn how to decide the combination of inputs to be used as per the resources available. Ensure that the production process works efficiently.

VI. Organization of the course

The course is organised as follows-

No	Block	Unit
1.	Introduction to production economics	1. Concepts of production economics
2.	Factors and costs	1. Factors and theory of production 2. Concepts of costs
3.	Assessment	1. Dynamics of assessment

VII. Theory

Block 1: Introduction to Production Economics

Unit 1: Concepts of production economics

Nature, scope and significance of agricultural production economics- Agricultural Production processes, character and dimensions-spatial, temporal - Centrality of production functions, assumptions of production functions, commonly used forms - Properties, limitations, specification, estimation and interpretation of commonly used production functions.

Block 2: Factors and costs

Unit 1: Factors and theory of production

Factors of production, classification, interdependence, and factor substitution -Determination of optimal levels of production and factor application -Optimal factor combination and least cost combination of production - Theory of product choice; selection of optimal product combination.

Unit 2: Concepts of cost

Cost functions and cost curves, components, and cost minimization -Duality theory

– cost and production functions and its applications -Derivation of firm's input demand and output supply functions -Economies and diseconomies of scale.

Block 3: Assessment

Unit 1: Dynamics of economic assessment

Technology in agricultural production, nature and effects and measurement - Measuring efficiency in agricultural production; technical, allocative and economic efficiencies - Yield gap analysis-concepts-types and measurement - Nature and sources of risk, modeling and coping strategies.

VIII. Practical

- Different forms of production functions
- Specification, estimation and interpretation of production functions
- Returns to scale, factor shares, elasticity of production
- Physical optima-economic optima
- Least cost combination
- Optimal product choice
- Cost function estimation, interpretation
- Estimation of yield gap
- Incorporation of technology in production functions
- Measuring returns to scale-risk analysis.

IX. Teaching Methods/ Activities

- Lectures
- Assignments (Group/individual)
- Group Discussions on working out
- Power point presentations by students
- Exploring the agricultural market and identification of industries and their type.

X. Learning outcome

After the successful completion of the course the student will be able to— Understand how the factors and output interact with each other. - Work out whether the production system is working efficiently and point out the loop holes.- Apply the knowledge of costs and profits to work out the demand and supply functions. This will result into more efficient decision making.

XI. Suggested Reading

- EO Heady. *Economics of Agricultural Production and resources use.*
- John P Doll and Frank Orazem. *Production Economics: Theory with application*
- Heady EO & Dillon JL. 1961. *Agricultural Production functions.* Kalyani Publishers, Ludhiana, India. 667 p.
- Baumol WG. 1973. *Economic theory and operations analysis*. Practice Hall of India Private Limited, New Dehli.626 p.
- Gardner BL & Rausser GC. 2001. *Handbook of Agricultural Economics* Vol. I Agricultural Production. Elsevier.

I. Course Title : Agricultural Marketing and Price Analysis

II. Course Code : AEC 503

III. Credit Hours : 2+1

IV. Why this course?

The ultimate aim of production process is to sell the produce in the market and generate income. Markets serves as platform where this exchange takes place. Agriculture markets are different from other markets due to the nature of the commodity. Thus, it is important to develop a strong foundation of agricultural marketing, its components and issues. The student needs to know about the multi-pronged ways of marketing the produce, agencies involved. In this modern era, it is important to understand how technology is transforming this sector.

V. Aim of the course

The course is designed to acquaint the students about the basics of dynamics of agricultural marketing. The content includes supply, demand and marketing of farm production, marketing functions and channels, marketing costs, margins and efficiency, agricultural prices, New marketing formats like e-marketing, e-NAM future trading, supply chain management, market intelligence etc.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to agricultural marketing	1. Introduction to agricultural marketing
2.	Agricultural markets	1. Aspects of agricultural marketing 2. Future marketing and government
3.	Advances in agricultural marketing	1. Use of information technology 2. Dynamics of price

VII. Theory

Block 1: Introduction to Agricultural Marketing

Unit 1: Introduction to agricultural marketing

New Concepts in Agricultural Marketing - Characteristic of Agricultural product and Production – Problems in Agricultural Marketing from Demand and Supply and Institutions sides. Market intermediaries and their role - Need for regulation in the present context - Marketable & Marketed surplus estimation. Marketing Efficiency - Structure Conduct and Performance analysis - Vertical and Horizontal integration - Integration over space, time and form-Vertical co-ordination.

Block 2: Agricultural Markets

Unit 1: Aspects of agricultural marketing

Different Forms of marketing: Co-operatives Marketing – APMC Regulated Marketing - Direct marketing, Farmer Producer Companies, e-NAM and marketing under e-NAM, e-marketing Contract farming and Retailing, Organized retailing - Supply Chain Management - State trading, Warehousing and other Government agencies -Performance and Strategies -Market infrastructure needs, performance and Government role - Value Chain Finance.

Unit 2: Future marketing and government

Introduction to Commodities markets and future trading - Basics of commodity futures - Operation Mechanism of Commodity markets – Price discovery - Hedging and Basis - Fundamental analysis - Technical Analysis – Role of Government/SEBI in promoting commodity trading and regulatory measures.

Block 3: Advances in Agricultural Marketing

Unit 1: Use of Information Technology

Role of Information Technology and Market Intelligence in marketing of agricultural commodities, -electronic auctions (e-bay), e-Chaupals, Agmarknet and Domestic and Export market Intelligence Cell (DEMIC).

Unit 2: Dynamics of price

Price forecasting – time series analysis – time series models – spectral analysis. Price policy and economic development – non-price instruments.

VIII. Practical

- Supply and demand elasticities in relation to problems in agricultural marketing.
- Price spread and marketing efficiency analysis.
- Marketing structure analysis through concentration ratios.
- Performance analysis of Regulated market and marketing societies. Analysis on contract farming and supply chain management of different agricultural commodities, milk and poultry products.
- Supply Chain Analysis - quantitative estimation of supply chain efficiency.
- Market Intelligence – Characters, Accessibility, and Availability Price forecasting.
- Online searches for market information sources and interpretation of market intelligence reports – commodity outlook.
- Technical Analysis for important agricultural commodities.
- Fundamental Analysis for important agricultural commodities.
- Presentation of the survey results and wrap-up discussion.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on price volatility and control measures prevailing.
- Power point presentations by students on government schemes.
- Visit to eNAM mandies, Warehouses, etc.

X. Learning outcome

After the completion of this course the student will be able to–

- Understand the whereabouts of agricultural marketing.
- The different forms of marketing existing in this sector.
- Gain expertise in market intelligence and price forecasting.

XI. Suggested Reading

- Acharya SS & Agarawal NL. 2004. *Agricultural Marketing in India*. Oxford and IBH Publishing company Pvt. Ltd. New Delhi.
- Acharya SS & Agarawal NL. 1994. *Agricultural Prices-Analysis and Policy*. Oxford and IBH Publishing company Pvt. Ltd. New Delhi.
- Richard H Kohls and Joseph N. Uhl: *Marketing of Agricultural products* by Collier MacMillan International.

I. Course Title : Macro Economics and Policy

II. Course Code : AEC-504

III. Credit Hours : 2+0

IV. Why this course?

The economy of the nation is governed by certain rules, regulation and principles. The students has to gain knowledge of the mechanism through which the large economies are controlled and ensure that welfare prevails. They are entitled to know the transactions between different markets and policies framed to keep value of money under control.

V. Aim of the course

The course envisages the concepts and principles of macroeconomics from classical to Keynesian theories. The other component deals with the monetary system-money, credit and banking system, value of money and economic activities, national income accounting and approaches to estimate national income theory of income and employment determination and inflation.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Conceptualising Macro economics	1. Introduction: Measurement and Concepts
2.	Theories of macroeconomics	1. Classical Macroeconomics 2. Income and spending: Keynesian Framework
3	Money, Consumption and Inflation	1. Money, Interest and Income 2. Theories of Aggregate Consumption and Investment 3. Inflation and Unemployment

VII. Theory

Block 1: Conceptualising Macro Economics

Unit 1: Introduction: Measurement and Concepts

Basic concepts and scope of Macro-economics, National Income Accounting: Methods of measurement of key macro-economic aggregates, relationship of national income and other aggregates (with numerical exercises), real and nominal income

Block 2: Theories of macroeconomics

Unit 1: Classical Macroeconomics

Say's Law, Quantity Theory of Money, aggregate labour supply and demand of labour, Classical theory of determining output, wages and prices.

Unit 2. Income And Spending: Keynesian Framework

Simple Keynesian model of income determination; Keynesian Multiplier- aggregate spending, taxation, transfer payments, foreign spending, balanced budget; budget surplus (with numerical exercises).

Block 3- Money, Consumption and Inflation

Unit 1: Money, Interest and Income

Goods market equilibrium-IS curve; Demand for Money, the Liquidity Preference

Theory – Liquidity Trap; asset market equilibrium- LM curve; simultaneous equilibrium in goods and asset market- effect of fiscal and monetary policy

Unit 2: Theories of Aggregarte Consumption and Investment

Absolute Income Hypothesis, Relative Income Hypothesis, Fisher's Inter-temporal Choice Model, Life-Cycle and Permanent Income Hypotheses; Profits and Accelerator Theory.

Unit 3: Inflation and Unemployment

Inflation: Nature, Effects and control; Types of inflation – demand pull, cost push-stagflation, core inflation, hyperinflation; Phillips curve.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on inflation.

IX. Learning outcome

After the completion of the course the student will be able to-Understand the concepts of national income, theories build up to understand macroeconomics. Understand better about the policies and government steps taken to control the economic transaction of the nation. Workout how the investment acts as a catalyst in national development.

X. Suggested Reading

- Stonier & Hegue. *A Text Book of Economic Theory*
- Samuelson PA. 1948. *Foundation of Economic Analysis*. Harvard University Press
- MC Vaish Allid. 1983. *Macro–Economics Theory*
- Gardner Ackley. 1961. *Macro–Economics Theory*: Macmillan, New York.
- TF Dernburg & DM Mcdougali-*Macro Economics*
- G. Sirkin – *Introduction to Macro–Economics Theory*
- RL Heibroker-*Understanding Macro–Economics*
- JK Mehta –*Macro Economics*
- Michael R Edgemand – *Macro-Economics: Theory & Policy*
- David' W Pearce –*The dictionary of modern Economics*

I. Course Title : Econometrics

II. Course Code : AEC 505

III. Credit Hours : 2+1

IV. Why this course?

Development of analytical skills is imperative to make students proficient in conducting quality research work. The knowledge of variables, their models, and problems encountered when dealing with variables will build up a compatibility with the analytical aspects.

V. Aim of the course

The course provides knowledge of the econometric methods like time series analysis, linear regression models and their application in economic analysis. The course provides an insight into the econometric problems in analyzing time series and cross section data.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to econometrics	1. Introduction
2.	Classical Regression	1. Classical Linear Regression 2. Breaking down of Classical assumptions
3.	Qualitative Variables	1. Qualitative variables and simultaneous equation models

VII. Theory

Block 1: Introduction to Econometrics

Unit 1: Introduction

Relationship between economic theory, mathematical economics, models and econometrics, methodology of econometrics-regression analysis.

Block 2: Classical Regression

Unit 1: Classical Linear Regression

Basic two variable regression – assumptions estimation and interpretation approaches to estimation – OLS and their properties – extensions to multi-variable models-multiple regression estimation and interpretation.

Unit 2: Breaking down of Classical assumptions

Violation of assumptions – identification, consequences and remedies for Multicollinearity, heteroscedasticity, autocorrelation – data problems and remedial approaches – model misspecification.

Block 3: Qualitative Variables

Unit 1: Qualitative variables and simultaneous equation models

Use of dummy variables- Introduction to simultaneous equations- identification problem

VIII. Practical

- Single equation two variable model specification and estimation
- Hypothesis testing transformations of functional forms and OLS application
- Estimation of multiple regression model
- Testing and correcting specification errors
- Testing and managing Multicollinearity
- Estimation of regressions with dummy variables

IX. Teaching Methods/ Activities

- Lectures.
- Assignments (Group/individual).

X. Learning outcome

After the completion of the course, the student will be able to-Understand the variables and the properties of regression models. Identify the problems in variables and remove them before conducting the analysis and avoid biased results.

XI. Suggested Reading

- Dorfman R. 1996. *Linear Programming and Economic Analysis*. McGraw Hill.
- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis, A. 1997. *Theory of Econometrics*. Barner & Noble.
- Maddala GS. 2002. *Econometrics*. Mc Graw-Hill.
- Pinndyck RS and Rubinfeld DL. 1990. *Econometric Models and Econometric Forecasts*. McGraw Hill.

I. Course Title : Agricultural Development and Policy Analysis

II. Course Code : AEC-506

III. Credit Hours : 2+0

IV. Why this course?

The ultimate aim of the economies is to attain a satisfactory level of development. Development ensures that there is not only increase in income but also the distribution is such that lesser inequalities exist. The students need to know what is development and its related concepts. All the policies framed are with one sole objective of increasing the welfare. Thus, once concept of development is build up, students can better understand policies and their genesis.

V. Aim of the course

Concept of economic development and policy, theories of development, performance of Indian agriculture. The process and implementation of policies over a period of time.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Basic concepts	1. Introduction
2.	Theoretical Concepts	1. Theories of Agricultural Development
3.	Performance and policies	1. Performance of Indian Agriculture
		2. Agricultural Policy: Process and Implementation

VII. Theory

Block 1: Introduction

Unit 1: Introduction

Role of agriculture in economic/ rural development – Evolution of thinking on agriculture and development; Agricultural development – meaning, stages and determinants – Population and food supply – need for sound agricultural policies

Block 2: Theoretical Concepts

Unit 1: Theories of Agricultural Development

Resource exploitation model- Conservation model- Location (Urban impact) model- Diffusion model- High pay-off input model-Induced Innovation Model- Agricultural R&D and Linkages

Block 3: Performance and policies

Unit 1: Performance of Indian Agriculture

Agrarian structure and land relations; trends in performance and productivity; agrarian structure and technology; credit, commerce and technology; capital formation; subsidies; pricing and procurement; Post Green Revolution agriculture; Production and productivity crisis in agriculture; Regional differences; Food Security, PDS system and Malnutrition.

Unit 2: Agricultural Policy: Process and Implementation

Instruments of Agricultural Policy; Process of agricultural policy formulation, implementation, Monitoring and Evaluation in India; Global experiences in participatory approach to Agricultural policy process; critical review of various elements of Indian agricultural policy-resource policies – credit policies – input and product marketing policies – price policies; WTO – Agreement on Agriculture; Planning models. Planning for utilization of resources and Indian Five Year Plans.

VIII. Teaching Methods/ Activities

- Lectures.
- Assignments (Group/individual).
- Group Discussions on evolution of Indian Agriculture and Development indices.
- Power point presentation by students on policies and their relevance.

IX. Learning outcome

After the completion of the course the student will be able to-Understand the concept of development and its preference over growth. Visualize how the agriculture sector is performing in this aspect. Understand the motive behind the policies and their implementation.

X. Suggested Reading

- Albert O. Hirschman 1958. *Strategy of Economic Development*. New Man Yale University
- Simon Kuznets 1965. *Economic Growth and Structures*. Oxford New Delhi.
- Das Gupta AK. 1965. *Planning and Economic Growth*. George Allen and Unwin London
- Robert E. Baldwin 1966. *Economic Development and Growth*. John Willey, New York

I. Course Title : Agricultural Finance and Project Management

II. Course Code : AEC 507

III. Credit Hours : 2+1

IV. Why this course?

Money is the fuel of driving all the economic activities. India is a land of small and marginal farmers. The financial conditions of the farmers is not so strong that they can finance themselves. They require credit to meet the requirements of inputs. Thus, the student should know the sources, principles involved and types of credit available. The institutions involved and on what grounds the finance is given to the farmer. What are the risks involved and how to overcome them.

V. Aim of the course

This course is designed with an objective to deliver knowledge of the principles, procedures, problems and policies relating to financing agricultural firms. In addition to this the students are also given knowledge about the research developments in the subject. The approach is analytic.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1	Introduction to Agricultural Finance	1. Basic Concepts: A review
2.	Credit and financial analysis	1. Credit and its aspects 2. Financial analysis
3	Project and risk management	1. Project Overview 2. Risk and its Management

VII. Theory

Block 1: Introduction to Agricultural Finance

Unit 1: Basic concepts: A Review

Role and Importance of Agricultural Finance. Financial Institutions and credit flow to rural/priority sector. Agricultural lending – Direct and Indirect Financing - Financing through Co-operatives, NABARD and Commercial Banks and RRBs. District Credit Plan and lending to agriculture/priority sector. Micro-Financing and Role of MFI's - NGO's, and SHG's.

Block 2: Credit and Financial Analysis

Unit 1: Credit and its aspects

Lending to farmers – The concept of 3 C's, 7 P's and 3 R's of credit. Estimation of Technical feasibility, Economic viability and repaying capacity of borrowers and appraisal of credit proposals. Understanding lenders and developing better working relationship and supervisory credit system. Credit inclusions – credit widening and credit deepening.

Unit 2: Financial analysis

Financial Decisions – Investment, Financing, Liquidity and Solvency. Preparation of financial statements - Balance Sheet, Cash Flow Statement and Profit and Loss Account. Ratio Analysis and Assessing the performance of farm/ firm.

Block 3- Project and Risk Management

Unit 1: Project Overview

Project Approach in financing agriculture. Financial, economic and environmental appraisal of investment projects. Identification, preparation, appraisal, financing and implementation of projects. Project Appraisal techniques – Undiscounted measures. Time value of money – Use of discounted measures - B-C ratio, NPV and IRR. Agreements, supervision, monitoring and evaluation phases in appraising agricultural investment projects. Net work Techniques – PERT and CPM.

Unit 2: Risk and its Management

Risks in financing agriculture. Risk management strategies and coping mechanism. Crop Insurance programmes – review of different crop insurance schemes - yield loss and weather based insurance and their applications.

VIII. Practical

- Development of Rural Institutional Lending;

- Branch expansion, demand and supply of institutional agricultural credit and Over dues and Loan waiving;
- An overview, Rural Lending Programmes of Commercial Banks, Lead Bank Scheme;
- Preparation of District Credit Plan, Rural Lending Programmes of Co-operative Lending Institutions;
- Preparation of financial statements using farm/firm level data, Farm credit appraisal techniques and farm financial analysis through financial statements;
- Performance of Micro Financing Institutions;
- NGO's and Self-Help Groups, Identification and formulation of investment projects;
- Project appraisal techniques – Undiscounted Measures and their limitations;
- Project appraisal techniques – Discounted Measures;
- Network techniques – PERT and CPM for project management;
- Case Study Analysis of an Agricultural project;
- Financial Risk and risk management strategies – crop insurance schemes;
- Financial instruments and methods – E banking, Kisan Cards and core banking.

IX. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions on inflation

X. Learning outcome

After the completion of the course the student will be able to-Understand the key issues of finance in Agriculture. Learn the techniques of assessing the worth of a project.

XI. Suggested Reading

- E Die Sollem H and Heady EO. (Ed.). *Capital and Credit Needs in Changing Agriculture*, Bauman.
- Hopkins A Barry, Peter Jo and Baker CB. *Financial Management in Agriculture*.
- Murray WG and Nelson AG. 1960. *Agricultural Finance*. Iowa State University
- Chanona C. 1969. *Agricultural Finance in India: Role of Commercial Banks*. Marketing and Economics Research Bureau, New Delhi.
- Gittinger JP. 1972. *Economic analysis of agricultural projects*, John Hopkins Univ. Press, Baltimore.
- Little IMD and JA Mirrless. 1974, *Project appraisal and planning for developing countries*, Oxford and IBH publishing Co. New Delhi.
- Arnold CH. 1972. *Project Evaluation, collected papers*, Macmillan.

I. Course Title : Linear Programming

II. Course Code : AEC-508

III. Credit Hours : 1+1

IV. Theory

Unit I

Decision Making- Concepts of decision making, introduction to quantitative tools, introduction to linear programming, uses of LP in different fields, graphic solution to problems, formulation of problems.

Unit II

Simplex Method: Concept of simplex Method, solving profit maximization and cost minimizations problems. Formulation of farms and non farm problems as linear programming models and solutions.

Unit III

Extension of Linear Programming models: Variable resource and price programming, transportation problems, recursive programming, dynamic programming.

Unit IV

Game Theory- Concepts of game theory, two person constant sum, zero sum game, saddle point, solution to mixed strategies, the rectangular game as Linear Programming.

V. Practical

- Graphical and algebraic formulation of linear programming models.
- Solving of maximization and minimization problems by simplex method.
- Formulation of the simplex matrices for typical farm situations.

I. Course Title : Research Methodology for Social Sciences

II. Course Code : AEC 509

III. Credit Hours : 1+1

IV. Why this course

Planning of research is very crucial to conduct a successful research. There is need to give an insight to the student about how to conduct a research, right from data collection to analysis and finally writing the references.

V. Aim of the course

The course deals with scientific methods of research, the initiation of an inquiry, formulation of research problems and hypotheses, the role of induction and deduction in research, collection and analysis of date and interpretation of results

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to research methodology	1. Concepts of research methodology
2.	Building up hypothesis and sample selection	1. Hypothesis: Framing and Testing 2. Sampling
3.	Data collection and analysis	1. Data collection 2. Data Analysis

VII. Theory

Block 1: Concepts of research methodology

Unit 1: Concepts of research methodology

Importance and scope of research in agricultural economics. Types of research – Fundamental vs. Applied. Concept of researchable problem – research prioritization – selection of research problem. Approach to research – research process.

Block 2- Building up hypothesis and sample selection

Unit 1: Hypothesis: Framing and Testing

Hypothesis – meaning – characteristics – types of hypothesis – review of literature – setting of Course Objective and hypotheses – testing of hypothesis.

Unit 2: Sampling

Sampling theory and sampling design – sampling error - methods of sampling – probability and non-probability sampling methods - criteria to choose. Project proposals – contents and scope – different types of projects to meet different needs – trade-off between scope and cost of the study. Research design and techniques – Types of research design.

Block 3- Data Collection and Analysis

Unit 1: Data Collection

Data collection – assessment of data needs – sources of data collection – discussion of different situations. Mailed questionnaire and interview schedule – structured, unstructured, open ended and closed-ended questions. Scaling Techniques. Preparation of schedule – problems in measurement of variables in agriculture. Interviewing techniques and field problems - methods of conducting survey – Reconnaissance survey and Pre testing.

Unit 2: Data Analysis

Data coding, tabulation, cleaning. –Multivariate analysis –factor analysis' PCA' cluster analysis. Universal procedures for preparation of bibliography – writing of research articles.

VIII. Practical

- Exercises in problem identification.
- Project proposals – contents and scope.
- Formulation of Objective and hypotheses.
- Assessment of data needs – sources of data – methods of collection of data.
- Methods of sampling – criteria to choose – discussion on sampling under different situations.
- Scaling Techniques – measurement of scales.
- Preparation of interview schedule.
- Field testing. Method of conducting survey.
- Exercise on coding, editing, tabulation and validation of data.
- Preparing for data entry into computer.
- Hypothesis testing – Parametric and Non-Parametric Tests.
- Exercises on format for Thesis/ Report writing.
- Presentation of the results.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After the successful completion of this course, student will be able to-Understand fundamentals of research. How to carefully plan out the research work and conduct it.

XI. Suggested Reading

- Baker CB. *Research Methodology in Agricultural Economics*
- Cohen MR and Nagel R. *An Introduction to Logic and Scientific Method*
- Devey J Logic. *The Theory of Enquiry*
- Dhondhyal SP. *Social Science Research and Thesis Writing*
- Ezekiel M. *Correlation Analysis*
- Heady EO. *Linear Programming Methods*
- Willson ER. *An Introduction to Scientific Research*
- Kumar A. 2008. *Research Methodology: A Survey*. Alts, New Delhi,

I. Course Title : Indian Economy: History and Contemporary Issues Credit

II. Course Code : AEC-510

III. Credit Hours : 2+0

IV. Why this course?

India is a developing economy. The evolution of the Indian economy will enlighten the student with how an economy develops. Students will understand how the policies and measures taken shape up the economy of the country.

V. Aim of the course

To introduce the students to the economic history over a period of time. It also highlights the contemporary issues of Indian economy.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	History of Indian Economy	1. India from Independence to Liberalization 2. India since 1980's (Liberalization and Beyond): Overview 3. Macro Trends Since 1990
2.	Contemporary Issues	1. Contemporary Issues

VII. Theory

Block 1- History of Indian Economy

Unit 1: India from Independence to Liberalization

An overview of the economic developments during the period 1947-1980; Objectives and strategies of planned economic development and the role of the State; Sectoral growth performance; savings and investment; Demographic trends and issues; education; health and malnutrition; Trends and policies in poverty; inequality and unemployment.

Unit 2: India Since 1980's (Liberalization And Beyond): Overview

Policy Changes since 1980s. The 1990 Crisis. Causes and Effects of liberalization. Regional differences: infrastructure, primary, secondary and tertiary sector.

Unit 3: Macro Trends Since 1990

Growth; Savings and Investment, Employment; productivity; diversification; Agro-based industries; competition policy; foreign investment, Regional differences.

Block 2- Contemporary Issues

Unit 1: Contemporary Issues

Monetary and Financial trends- areas of government spending in India, Capital expenditure, revenue expenditure, plan expenditure, non plan expenditure, Deficits (fiscal, primary, revenue), impact of fiscal deficit on economy, Capital receipts, revenue receipts, tax and non tax revenue, direct and indirect taxes, need to rationalize tax structure. Goods and Services Tax (GST). Union Budget, Zero base budgeting, Gender budgeting, Fiscal devolution and centre state financial relations in India, WPI, CPI implicit deflators. Foreign Trade policy.

VIII. Teaching Methods/ Activities

- Lectures
- Power point presentation by students on monetary and fiscal policy in past and present.
- Assignments (Group/individual).
- Group Discussions on Tax and its reforms.

IX. Learning outcome

After the completion of the course the student will be able to-Visualize how the Indian economy has evolved. Get acquainted with the basic steps involved in the working of the national economy.

X. Suggested Reading

- Dutt and Sundaram. *Indian Economy*

I. Course Title : International Economics

II. Course Code : AEC 511

III. Credit Hours : 2+1

IV. Why this course?

The era of Globalisation, liberalization and privatization has unified the whole world. There is trade across national boundaries and one economy has effect on the other. Getting familiar with national economy is not sufficient to understand the mechanism of trade and economic aspects. Thus, this course is designed to teach student about the trade as international level.

V. Aim of the course

The major objective of this course is to give an insight of the interactions between national economies. What are the theories governing the trade across national boundaries. The methods involved to regulate the international trade and institutions involved.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction	1. Concepts of International Economics
2.	Models, Rate and terms of trade	1. Barriers to trade
		2. Models of trade
		3. Rates and Terms of trade
3	Institutions	1. Trades Institutions

VII. Theory

Block 1- Introduction

Unit 1: Concepts of International Economics

Scope and Significance of International Economics – The role of trade- General Equilibrium in a Closed Economy (Autarky Equilibrium) – Equilibrium in a Simple Open Economy - Possibility of World Trade - Trade gains and Trade Equilibrium.

Block 2- Models, Rate and Terms of Trade

Unit 1: Barriers to trade

Tariff, Producer Subsidy, Export Subsidy, Import Quota and Export Voluntary Restraints- The Case of Small Country and Large Country Case.

Unit 2: Models of trade

Ricardian Model of Trade- Specific Factors Model- Heckscher - Ohlin Model - Trade Creation and Trade Diversion – Offer Curve - Export Supply Elasticity and Import Demand Elasticity – Comparative Advantage and Absolute Advantage.

Unit 3: Rates and Terms of trade

Official Exchange Rate and Shadow Exchange Rate - Walra's Law and Terms of Trade – Trade Blocks.

Block 3- Institutions

Unit 1: Trades Institutions

IMF, World Bank, IDA, IFC, ADB – International Trade agreements – Uruguay Round – GATT – WTO.

VIII. Practical

- Producer's Surplus, Consumer's Surplus, National Welfare under Autarky and Free Trade Equilibrium with small and large country assumption.
- Estimation of Trade Gains
- Estimation of competitive and comparative measures like NPC, EPC, ERP and DRC
- Estimation of Offer Curve Elasticity
- Estimation of Effect of Tariff, Export Subsidy, Producer Subsidy, Import Quota and Export Voluntary Restraints on National Welfare
- Estimation of Ricardian Model
- Estimation of Effect of Trade under Specific Factor Model
- Estimation of trade Equilibrium under Heckscher -Ohlin model

- Trade Creation and Diversion.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Power point presentation on International Trade in current scenario.

X. Learning outcome

After successful completion of the course the student will be able to –Understand how trade take place between nations. Be able to work out strategies to maintain a favourable trade balance. Understand how the institutions play role in regulating the cross country trade and deal with the issues.

XI. Suggested Reading

- Kindelberger and Joshi PK. 2016. *International Economics* AITBS Delhi-110051
- Brouwer F. *International Trade and Food Security*. LEI - Wageningen UR, The Netherlands.

I. Course Title : Institutional Economics
II. Course Code : AEC 512
III. Credit Hours : 1+0

IV. Why this course?

Institutions are involved in framing of economic development. The human behavior is governed by the institutions working in their environment. Thus, the student need to understand the institutions and their working.

V. Aim of the course

To develop critical and informed understanding about institutions, their role in the working of economy. Exposure of issues, policies & regulations and its application in agricultural system

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1	Introduction	1. Basics of Institutional Economics
2.	Approaches	1. Institutional changes & Resource allocation 2. Group and collective Approach
3.	Law Protection and Institutions	1. Property rights 2. Agrarian Institutions

VII. Theory

Block 1: Introduction

Unit 1: Basics of Institutional Economics

Old and New Institutional Economics – Institutional Economics vs Neo-classical Economics. Definition of institutions – Distinction between institutions and organizations – Institutional evolution.

Block 2: Approaches

Unit 1: Institutional changes & Resource allocation

Institutional change and economic performance - national and international economic institutions. Transaction cost economics – Transaction costs and the allocation of resources. Transaction costs and efficiency. Asymmetric information - Moral hazard and Principal-Agent problem.

Unit 2: Group and collective Approach

Free rider problem – path dependency – Interlinked transactions. Collective action and the elimination of free-rider problem - The logic of collective action and its role in reducing free rider problem – theory of Groups. Rent seeking – interest groups and policy formulation.

Block 3: Law Protection and Institutions

Unit 1: Property rights

Economic analysis of property rights- property rights regimes – private property – State Property - Common property Resources (CPRs) – public goods and club goods.

Unit 2: Agrarian Institutions

Special features of institutional arrangements in agriculture – Transaction costs in agriculture - Case Studies - Theories of agrarian institutions - tenancy institutions.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on Property rights

IX. Learning outcome

After successful completion of this course the student will be able to-Understand institutions and their roles in economic development. Know about the policies and their issues in an institutions.

X. Suggested Reading

- Pearce DW –*The dictionary of modern Economics*

I. Course Title : Natural Resource and Environmental Economics

II. Course Code : AEC 513

III. Credit Hours : 1+1

IV. Why this course?

Sustainable development is the need of the hour. The economic activities affect not only the society but also the environment. Every activity has its social cost. The students, hence will be taught about the economic aspect of environment.

V. Aim of the course

To understand about economics of environment and social costs incurred due to economic development. Work out methods to maintain environment quality and reduce social costs

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to natural resource and environmental economics	1. Basic Foundation
2.	Insight of the subject	1. Theories and economics of natural resources 2. Functioning of Market
3	Dealing with Issues and sustainability	1. Environmental Issues 2. Regulations 3. Sustainability aspects

VII. Theory

Block 1- Introduction to natural resource and environmental economics

Unit 1: Basic Foundation

Concepts, Classification and Problems of Natural Resource Economics – Economy Environment interaction – The Material Balance principle, Entropy law-Resources Scarcity - Limits to Growth - Measuring and mitigating natural resource scarcity – Malthusian and Recardian scarcity – scarcity indices - Resource Scarcity and Technical Change.

Block 2- Insights of the subject

Unit 1: Theories and economics of natural resources

Theory of optimal extraction renewable resources –economic models of oil extraction-efficiency - time path of prices and extraction - Hotelling's rule, Solow-Harwick's Rule. Theory of optimal extraction exhaustible resources – economic models of forestry and fishery.

Unit 2: Functioning of Market

Efficiency and markets – market failures - externalities – types - property rights – transaction costs – Coase's theorem and its critique - public goods - common property and open access resource management - Collective action.

Block 3- Dealing with the issues and sustainability

Unit 1: Environmental Issues

Environmental perspectives - biocentrism, sustainability, anthropocentrism - Environmental problems and quality of environment - Sources and types of pollution -air, water, solid waste, land degradation – environmental and economic impacts - Economics of pollution control - efficient reduction in environmental pollution.

Unit 2: Regulations

Environmental regulation – economic instruments - pollution charges – Pigovian tax - tradable permits – indirect instruments – environmental legislations in India.

Unit 3: Sustainability aspects

Concept of sustainable development – Economic Perspective – Indicators of sustainability Relation between development and environment stress-Environmental Kuznet's curve Environmental Accounting – resource accounting methods –

International Environmental Issues – climate change – likely impacts – mitigation efforts and international treaties.

VIII. Practical

- Exhaustible resource management – optimum rate of oil extraction.
- Renewable resource management – optimum harvest of Forestry/fishery.
- Exercise on pollution abatement-I.
- Exercise on pollution abatement-II.
- Concepts in valuing the environment.
- Taxonomy of valuation techniques.
- Productivity change method – substitute cost method – Hedonic price method – Travel cost method – Contingent valuation methods.
- Discount rate in natural resource management.
- Environment impact assessment
- Visit to Pollution Control Board.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).

X. Learning outcome

After successful completion of this course, the student will be able to-Work out the plan for extraction / use of natural resource in most economical way. Understand the environment and its pollution. Learn how markets are affected if environment is not taken into consideration. Gain proficiency in rules and regulation governing economic aspect of environment.

XI. Suggested Reading

- Pearce DW and Turner RK. *Economics of Natural Resource and Environment*
- Kwak J. *Economism: Bad Economics and the Rise of Inequality*
- Tietenberg T and Lewis L. *Environmental and Natural Resource Economics*
- Schwarz PM. *Energy Economics*

I. Course Title : Commodity Future Trading Credits

II. Course Code : AEC 514

III. Credit Hours : 2+0

IV. Why this course?

Risk is involved in marketing. Price fluctuation is a very common phenomenon in agriculture marketing. In such situation selling of commodity in future market serves as a resort to insulate from this uncertainty. Thus, knowledge of futures market is helpful in ...

V. Aim of the course

To disseminate the knowledge about risk mitigating measures especially future trading. The future trading in agricultural commodities is increasing day by day therefore the role of SEBI, functioning of commodity exchanges are discussed.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to commodity market	1. Concepts of commodity future trading
2.	Techniques and risks in commodity market	1. Technical aspects 2. Risk and its Management
3.	Commodity exchange and market analysis	1. Commodity Exchange–A review 2. Analysis of commodity market

Theory

Block 1- Introduction to commodity market

Unit 1: Concepts of commodity future trading

History and Evolution of commodity markets – Terms and concepts: spot, forward and futures Markets – factors influencing spot and future markets. Speculatory mechanism in commodity futures.

Block 2- Techniques and Risks in Commodity Market

Unit 1: Technical aspects

Transaction and settlement – delivery mechanism - role of different agents - trading strategies -potential impact of interest rate, Foreign Exchange, FDI in Commodity Markets.

Unit 2: Risk and its Management

Risk in commodity trading, importance and need for risk management measures - managing market price risk: hedging, speculation, arbitrage, swaps - pricing and their features.

Block 3- Commodity exchange and market analysis

Unit 1: Commodity Exchange – A review

Important global and Indian commodity exchanges - contracts traded – special features -Regulation of Indian commodity exchanges - FMC and its role.

Unit 2: Analysis of commodity market

Fundamental Vs Technical analysis – construction and interpretation of charts and chart patterns for analyzing the market trend – Market indicators – back testing. Introduction to technical analysis software – analyzing trading pattern of different commodity groups.

VII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions.
- Power point presentations by students.

VIII. Learning outcome

After successful completion of this course, the student will be able to-The basic concepts of commodity markets. The national and international commodity markets.

IX. Suggested Reading

- Kaufman PJ. *The Concise Handbook of Futures Markets*: Jhon Wiley & Sons
- Purcell WD. *Agricultural Futures and Options: Principles and Strategies*: MacMillan Publications
- Wasendorf RR & McCaffery *All About Commodities from the Inside Out*. McGraw Hill

I. Course Title : Development Economics Credit

II. Course Code : AEC-515

III. Credit Hours : 2+0

IV. Why this course?

Development is more important than growth. The development of a nation ensures that condition of welfare prevails. The students has to understand different measures of development. How to measure them and relevant theories.

V. Aim of the course

To develop concept of growth and development. Methods and theories of measuring development. Study of different developed economies will give exposure towards measures to create economic upliftment.

VI. Learning outcome

After successful completion of this course, the student will be able to-Measure the development using different methods. Understand the theories of development and relate it to real world.

VII. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to development economics	1. Conceptions of Development
2.	Theories and comparison	1. Theories of Economic growth and development 2. Comparative Economic Development

VIII. Theory

Block 1- Introduction to Development Economics

Unit 1: Conceptions of Development

Development Economics – Scope and Importance - Economic development and economic growth - divergence in concept and approach - Indicators and Measurement of Economic Development –GNP as a measure of economic growth – New Measures of Welfare – NEW and MEW – PQLI – HDI – Green GNP - Criteria for under development – Obstacles to economic development –Economic and Non-Economic factors of economic growth- Development issues, poverty, inequality, unemployment and environmental degradation.

Block 2- Theories and comparison

Unit 1: Theories of Economic growth and development

Classical theories- Adam smith - Ricardo- Malthus, Marx's theory of economic development; Schumpeter's theory, Approaches to development- low income equilibrium trap - critical minimum effort- The Strategy of economic development- Balanced vs. Unbalanced growth, choice of technique, investment criteria, big push theory, Rostow's stages of Economic Growth, unlimited supply of labour; social and technological dualisms; roles of capital accumulation, human capital and technological change in economic development, Models of economic growth Harrod-Domar, Kaldor, Mahalanobis, Lewis, FeiRanis, Input-Output, multisectoral models.

Unit 2: Comparative Economic Development

Countries selected for case studies -USA, Japan, China and India; Overview of economic development is selected countries; agrarian surplus and the role of the peasantry in economic development; industrial revolution; division of labour, organisation of work and industrial production, the role of the State in developmental transition

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on inflation

X. Suggested Reading

- Blaug M. 1986. *Economic History and the History of Economic Thought*
- Chenery HB and TN Srinivasan. *Handbook of Development Economics*
- Baldwin RE. *Economic Development and Growth*. John Willey, New York

I. Course Title : Mathematics for Agricultural Economics

II. Course Code : STAT/AEC

III. Credit Hours : 3+0

IV. Why this course?

Knowledge of calculus is basic requirement for carrying out simple calculations.

V. Aim of the course

To solve various mathematical problems in economic research. Calculations are integral part of research analysis therefore it has wide application in economic studies.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction	1. Preliminaries
2.	Variables and functions	1. Variables and functions 2. Differentiation of functions
3.	Overview of linear algebra	1. Linear Algebra 2. Optimization of functions 3. Integration of functions

VII. Theory

Block 1- Introduction

Unit 1: Preliminaries

Logic and proof techniques; sets and set operations; relations; functions and their properties; number systems

Block 2- Variables and functions

Unit 1: Variables and functions

Specific functions is economic theory. Elementary analytical geometry-gradient and equation of straight line. Standard equations and simple properties of circle, parabola and rectangular hyperbola.

Unit 2: Differentiation of functions

Limit and continuity. Differentiation, theorems of differentiation, differentiation of logarithmic and exponential functions, function of a function, derivative of higher order, partial derivatives. Application of derivatives to determine average and marginal values in economic analysis; determination of elasticities; points of inflexion; linear homogenous production functions; derivation of average and marginal curves.

Block 3- Overview of Linear Algebra

Unit 1: Linear Algebra

Determinants, evaluation and properties of determinants, Vectors and vector spaces, Matrices, notations and operations, laws of matrix algebra; transpose and inverse of matrix; Solution of linear and quadratic equations involving one variable, simultaneous equations, application of determinants and matrices in solution of equation for economic analysis.

Unit 2: Optimization of functions

Optimization- unconstrained, maxima and minima, constrained optimization, Lagrange multiplier and their economic applications for optimization problems of cost, production, demand and supply.

Unit 3: Integration of functions

Integration as a reverse process of differentiation, methods of integration, reduction formulae, definite integral, use of integration to determine relation between average and marginal value. Capitalization over time, estimation of returns from capital goods over time. Pareto distribution.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Power point presentations

IX. Learning outcome

After successful completion of this course, the student will be able to-Develop expertise in calculus operations.

Course Title with Credit Load
Ph.D. in Agricultural Economics

Major Courses: 12 credits

Course Code	Course Title	Credit Hours
AEC-601	Advanced Micro Economic Analysis	2 (1+1)
AEC-602	Advanced Macro Economic Analysis	2 (2+0)
AEC-603	Advanced Econometrics	3 (2+1)
AEC-604	Advanced Production Economics	3 (2+1)
Common	Research and Publication Ethics	2(2+0)

Minor Courses: 06 credits

a. It is suggested the student may choose at least one out of three courses listed below as part of minor courses as these are related to policy advocacy and bring in global perspectives with an aim to build a larger understanding of the subject to the student.
b. Further, it is suggested that the student may choose the remaining Courses from any other discipline including the disciplines of Agril. Economics/ ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/ HoD.

AEC-606	Advanced Agricultural Marketing and Price Analysis	3 (2+1)
AEC-607	Quantitative Development Policy Analysis	2 (1+1)
AEC-608	Natural Resource Management	3 (2+1)
AEC-609	Environmental Economics	3(2+1)

Minor courses may be taken from above list or subjects closely related to a student's major subject

Supporting Courses: 05 credits

AEC-605	Operations Research	3 (2+1)

One course of 600 series of 2 credits from Statistics or computer discipline may be taken depending upon availability.

- Some of these courses are available in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform.
- If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the HoD/ BoS.

- It is also suggested that the student may choose the Supporting Courses other than the listed courses, provided the opted courses are related to the research problem selected by the student and be mandatorily approved by the Student Advisory committee/HoD".

AEC-660	Doctoral Seminar -I	1(1+0)
AEC-661	Doctoral Seminar -II	1(1+0)
	RESEARCH	75
	Total	100

There will be two Doctoral Seminar and a research scholar has to published one review paper as output of these seminar. At Ph.D. level, Research Plan Proposal (RPP) be delivered by the end of SEM II

Course Contents
Ph.D. in Agricultural Economics

I. Course Title : Advanced Micro Economic Analysis
II. Course Code : AEC 601
III. Credit Hours : 1+1

IV. Why this course?

This course is required to upscale the knowledge of students about micro economics. So that they can get a deeper and better understanding of the subject.

V. Aim of the course

To gain fundamental understanding of consumer behavior, producer's strategy, market structure through which transactions take place and human and firms interact. Develop foundation of scarce resource allocation for optimum results.

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1.	Consumer Theory	1. Consumer Theory
2.	Market and General quilibrium	1. Market 2. General Equilibrium
3.	Market failure and welfare	1. Market Failure 2. Welfare Economics

VII. Theory

Block 1- Consumer Theory

Unit 1: Consumer Theory

Theory of consumer behavior – Duality in consumer theory - expenditure function and indirect utility function - Measurement of Income Effect and Substitution Effect. Measurement of Changes in Consumers' Welfare – Consumer's Surplus, Compensating Variation and Equivalent Variation - Dynamic versions of demand functions – Integrability of demand functions. Demand Models – Linear Expenditure System, Almost Ideal Demand System. Applications of consumer theory – Household model and time allocation – Labour supply decisions by households.

Block 2- Market and General Equilibrium

Unit 1: Market

Perfect competition – Monopoly, monopolistic competition and oligopoly. Oligopoly models – collusive and non-collusive models of oligopoly - Cournot model, Chamberlin model, Stackleberg solution.

Unit 2: General Equilibrium

General equilibrium theory – Conceptual overview - General equilibrium conditions with Production and Consumption. Existence, Uniqueness and Stability of general competitive equilibrium. Walrasian general equilibrium – Mathematical derivation of conditions for general equilibrium.

Block 3- Market Failure and Welfare

Unit 1: Market failure

Market failure - Incomplete markets - Asymmetric information – Principal-Agent problem, adverse selection and moral hazard. Externalities – Network externalities, Public goods – Optimal provision of public goods.

Unit 2: Welfare Economics

Welfare Economics - Concepts, problems, approaches and limitations of Welfare Economics, Pareto conditions of maximum welfare – Criteria for social welfare - Social Welfare functions, Social versus Private costs and benefits.

VIII. Practical

- Problems in consumer utility maximization
- Estimation of income and substitution effects;
- Estimation and comparison of Consumer's surplus, equivalent variation and compensating variation.
- Estimation of demand models – Derivation and estimation of labour supply equations from household models comparative static analysis in consumption.
- Advanced problem solving in price determination under perfect competition, monopoly, oligopoly and monopolistic competition.
- Game theory models.
- Problems solving in General Equilibrium Theory and Welfare Economics.
- Problems in public goods provision.

IX. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions

X. Learning outcome

After successful completion of the course, the student will be able to-Understand the different market competition. Work out strategies for attaining equilibrium in the market.

XI. Suggested Reading

- Henderson JM and Quandt RE. *Microeconomic Theory: A Mathematical Approach* Tata McGraw Hill Publishing Co Ltd
- Koutsoyiannis A. *Modern Micro Economics*. Macmillan Press Ltd
- Ferguson and Gould. *Micro Economic Theory*. Richard D Erwin Inc USA

I. Course Title : Advanced Macro Economics

II. Course Code : AEC-602

III. Credit Hours : 2+0

IV. Why this course?

A deeper understanding of the conceptual and structural framework is imperative to develop vision of a student about how the knowledge of various macroeconomic models is applied in real economy.

V. Aim of the course

To understand the functioning of national economy, its history and models. The policies governing the modern economic system and concerned institutions.

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1.	Introduction	1. Overview
2.	Economic Models	1. Open Economy Models 2. Dynamic Macroeconomic Models
3.	Business cycle and pollicies	1. Business Cycles 2. Macroeconomic Polices

VII. Theory

Block 1- Introduction

Unit 1: Overview

Conceptual framework - Classical, Keynesian, Neo-Classical, and Neo-Keynesian macroeconomics; Review of Keynes-Classical Synthesis; Aggregate Demand and Supply in the closed economy with fixed and variable price level- determination of wage, prices, output and employment

Block 2- Economic Models

Unit 1: Open Economy Models

Exchange rate determination; purchasing power parity; asset market approach; Short-run open economy models; Mundell-Fleming model- exchange rate regime: perfect capital mobility under fixed and flexible exchange rate; effectiveness of fiscal policy and monetary policy; Dornbusch's overshooting model; monetary approach to balance of payments; international financial markets

Unit 2: Dynamic Macroeconomic Models

Introduction to dynamic macroeconomic Models; Dynamic aggregate demand and supply – short and long term equilibrium- rational expectations approach

Block 3: Business Cycle and Policies

Unit 1: Business Cycles

Business cycle and its alternative equilibrium model, Stability analysis Economics of Great Events-Depression, Hyperinflation and Deficits; Advances in Business Cycle Theory; Real Business Cycles & Neo-Keynesian Economics

Unit 2: Macroeconomic Polices

Monetary policy - Design of Monetary Policy; Inflation Targeting, Fiscal Policy - Government Budget Constraint: The Arithmetic of Deficits and Debt, Current versus Future Taxes, the Evolution of Debt-to-GDP Ratio; Public Borrowing-Internal and external aid, Deficit financing, Development Financing; BOP & Adjustment Policies - Foreign Exchange Policy -International macro-economic policies, IMF, IBRD, UNCTAD.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

IX. Learning outcome

After successful completion of this course the student will be able to-Figure out how policies are framed to safe guard the national economy. Understand the rationale behind the working of different economy.

X. Suggested Reading

- Heibroker RL. *Understanding Macro Economics.*
- Mehta JK. *Macro Economics.*
- Edgemand MR. *Macro-Economics: Theory & Policy.*
- David' W Pearce. *The dictionary of modern Economics.*
- Allen RGD. 1968. *Macro–Economic Theory: A Mathematical Treatment*. London: Macmillan.
- Stanlake GF. *Macro–Economics: An Introduction*. Longman, London.
- Mithai DM. 1981. *Macro–Economics: Analysis and Policy*. Oxford and IBH, New Delhi.
- Hicks JR *Critical Essays in Monetary Theory.*
- Nawiyn WT. *Theory of Money*.

I. Course Title : Advanced Econometrics

II. Course Code : AEC 603

III. Credit Hours : 2+1

IV. Why this course?

The heart of any research is carrying out the analysis with the most appropriate model. The results obtained are crucial for the researchers. Thus, this course acts as the centre point of building up analytical framework of research. The students need to learn building up of models that will be used to test the hypothesis framed. Use different analysis depending upon the requirement and type of data.

V. Aim of the course

The course aims at providing the knowledge and command over analysis of data collected to get the desired result. Train the student in use of econometric models.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Concepts	1. Review
2.	Least squares and dummy variables	1. Concept of Least Squares 2. Dummy Variable
3.	Econometric models	1. Models and their extensions 2. Simultaneous equation modles

VII. Theory

Block 1: Concepts

Unit 1: Review

Review of classical regression model – review of hypothesis testing – restrictions on parameters – single equation techniques.

Block 2: Least Squares and Dummy Variables

Unit 1: Concept of least squares

Ordinary least squares – weighted least squares - generalized least squares – method of principal components – instrumental variables method - maximum likelihood method - errors in variables, non-linearity and specification tests – non spherical error terms.

Unit 2: Dummy Variable

Dummy variables - Qualitative and truncated dependent variables - limited dependent variables –LPM, probit and logit models, their multinomial extensions.

Block 3: Econometric Models

Unit 1: Models and their extensions

Autoregressive distributed lag models – panel data fixed and random effects models and their extensions.

Unit 2: Simultaneous equation models

Simultaneous equation methods –identification – estimation by indirect least squares 2SLS, PIML, SURE, 3SLS

VIII. Practical

Estimation of multiple regression model - GLS estimation methods - testing misspecification errors – Testing and Managing multicollinearity, heteroscedasticity and autocorrelation - estimation of LPM, Logit and Probit models - comparing two regressions - Chow test - estimation of distributed lag models – panel data random and fixed effects models - Indirect least squares 2SLS, SURE, 3SLS, estimation of simultaneous equation models.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/ individual).
- Group Discussions

X. Learning outcome

After successful completion of the course, the student will be able to–

- Analyse the data collected for testing the framed hypothesis.
- Get expertise in analytical framework.

XI. Suggested Reading

- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis A. 1997. *Theory of Econometrics*. Barner & Noble.

I. Course Title : Advanced Production Economics

II. Course Code : AEC 604

III. Credit Hours : 2+1

IV. Why this course?

There is requirement of getting acquainted with decision making process in case of factors and products. The researcher needs to understand about working on production process and work out suitable suggestions to improve it.

V. Aim of the course

The course deals with the concept of advanced production economics. The exposition would be mathematically oriented. The course would also cover the analysis of production functions, its interpretation, decision making with multiple input use, factor sharing and decision making under risk and uncertainty.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Consumer Theory	**1.** Production Process
2.	Market and General quilibrium	1. Production Functions and characteristics
3.	Market failure and welfare	1. Decision Making in Production 2. Technology, Efficiency and Risk Management 3. Programming

VII. Theory

Block 1: Production process

Unit 1: Production Process

Agricultural Production process – Relationship between farm planning and production economics-scope of agricultural production and planning-methods/ procedures in agro-economic research and planning.

Block 2: Production Function

Unit 1: Production Functions and characteristics

Production functions, components, assumptions, properties and their economic interpretation - Concepts of homogeneity, homotheticity,, APP, MPP, elasticities of substitution and their economic relevance – Production relations – optimality- Commonly used functional forms, nature, properties, limitations, estimation and interpretation - linear, Spillman - Cobb Douglas, quadratic, multiplicative (power) functional forms - Translog, and transcendental functional forms - CES, production functional forms-Conceptual and empirical issues in specification, estimation and application of production functions- Analytical approaches to economic optimum - Economic optimum – determination of economic optimum with constant and varying input and output prices - Economic optimum with production function analysis - input use behaviour.

Block 3: Dynamics of production process

Unit 1: Decision Making in Production

Decision making with multiple inputs and outputs – MRT and product relationship- cost of production and adjustment in output prices-single input and multiple product decisions- Multi input, and multi product production decisions - Decision making with no risk -Cost of wrong decisions - Cost curves – Principles and importance of duality theory - Correspondence of production, cost, and profit functions - Principles and derivation of demand and supply functions

Unit 2: Technology, Efficiency and Risk Management

Technology, input use and factor shares -effect of technology on input use-decomposition analysis-factor shares-estimation methods- Economic efficiency in agricultural production – technical, allocative and economic efficiency – measurement -Yield gaps analysis – concepts and measurement - Risk and uncertainty in agriculture – incorporation of risk and uncertainty in decision making – risk and uncertainty and input use level-risk programming.

Unit 3: Programming

Simulation and programming techniques in agricultural production-Multiple Objective Programming (MOP) – Goal programming, Weighted sum and Compromise programming – applications.

VIII. Practical

Estimation of different forms of production functions- Optimal input and product choice from estimated functions-Derivation of demand and supply functions and estimation-Estimation of cost function and interpretations-Optimal product and input choice under multi input and output system-Estimation of factor shares from empirical functions estimated-Estimating production functions incorporating technology changes: Decomposition analysis and incorporation of technology-Estimation of efficiency measures – Stochastic, probabilistic and deterministic frontier production functions-Risk programming – MOTAD-Quadratic programming-Simulation models for agricultural production decisions-Goal programming – Weighted, lexicographic and fuzzy goal programming-Compromise programming.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After successful complétion of the course, the student will be able to-Get familiar with different production function and use them in practise and come out with useful decision. Work out the efficiency of the production process and use models for finding the optimum solution.

XI. Suggested Reading

- Baumol WG. 1973. *Economic theory and operations analysis*. Practice Hall of India Private Limited, New Dehli. 626 p.
- Gardner BL and Rausser GC. 2001. *Handbook of Agricultural Economics* Vol. I Agricultural Production. Elsevier.
- Heady EO. 1952. *Economics of Agricultural Production and resources use*. Practice Hall of India.
- Heady EO and Dillon JL. 1961. *Agricultural Production functions*. Kalyani Publishers, Ludhiana, India. 667 p.

I. Course Title : Operations Research

II. Course Code : AEC-605

III. Credit Hours : 2+1

IV. Why this course?

In sphere of management it is important, to take correct decision of assigning tasks and roles to individuals. The business is full of uncertainity and in this situation the manager has to take decision. It becomes imperative to gain knowledge of models used for finding this solution of performing well.

V. Aim of the course

To gain elementary knowledge of solving problems and decision making for managing farming and organisation in resource constraint in order to achieve the objective.

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1	Concepts	1. Concepts
2	Inventory and models	1. Inventory- A Review 2. Models
3	Decision making	1. Decision making 2. Game theory

VII. Theory

Block 1: Concepts

Unit 1: Concepts

Elementary concepts and objectives of Operations Research, Review of Linear programming - Assumptions & Methods, Non-linear programming problem - Quadratic programming, Multi Objective Programming (MOP)

Block 2: Inventory and Models

Unit 1: Inventory- A Review

Inventory control models, costs involved in Inventory management, types of inventory, Economic order quantity model, Waiting line models: Waiting line problem, Characteristics of a waiting line system, Single channel model,

Unit 2: Modles

Markov Chains, Sequencing, Replacement models, Transportation and Assignment problems.

Block 3: Decision Making

Unit 1: Decision Making

Decision making under risk and uncertainties, decision problem, maximax criterion, maximin criterion, minimax regret criterion, Laplace criterion, Pay off tables, Decision trees, Expected value of perfect information.

Unit 2: Game Theory

Game Theory – Two-person Zero sum game, Simulation, Network Analysis- PERT & CPM.

VIII. Practical

- Linear and Non-linear programming problem,
- Quadratic programming, Multi-Objective Programming- Goal Programming,
- Lexicographic, Weighted Sum, Determining economic order quantity, reorder levels of EOQ model.

- Waiting line problem, Problems on Markov Chains, Sequencing and Replacement models.
- Formulating and solving transportation type problems, Assignment problems as a special type of transportation problem.
- Solving deterministic and probabilistic queuing models Structuring and solving decision trees for optimal decisions Game theory, Simulation, Developing network (PERT/CPM) diagrams and determining the critical path.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After successful completion of this course, the student will be able to-
Gain expertise in formulating problems of management into mathematical form and work out the optimum solutions.
Apply the knowledge of different models in better decision making and controlling of the firm.

XI. Suggested Reading

- Taha HA. *Operations Research: An Introduction*.
- Veerabhadrappa H. *An Introduction to Operations Research*.
- Gupta PK and Hira DS. *Operations Research*.
- Sharma R. *Operations Research*.
- Sharma JK. *Operation Research*.
- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis A. 1997. *Theory of Econometrics*. Barner & Noble.

I. Course Title : Advanced Agricultural Marketing And Price Analysis
II. Course Code : AEC 606
III. Credit Hours : 2+1

IV. Why this course?

Efficient markets, connectivity in markets, facilities of transport and storage ensure that there is growth in marketing of the produce as well as the industries based on those produce. The decision of selling the produce at the right time, and at a higher price is crucial to ensure remunerative returns to the farmer. Thus, this course is required to enhance the knowledge to students in agricultural markets and price analysis.

V. Aim of the course

To impact adequate knowledge and analytical skills in the field of agricultural marketing and enhance expertise in improving the performance of the marketing institutions and the players in marketing of agricultural commodities. Learning outcome: After successful completion of this course, the student will be able to-Gain the knowledge of marketing and agricultural prices. Work out the interaction between different markets and analyse their working. Gain expertise in forecasting of price and build up market intelligence.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Concepts	1. Agricultural Marketing- Insights
2.	Marketing Institutions and Dynamics	1. Institutions and their functions 2. Market Dynamics
3.	Techniques	1. Commodity marketing 2. Models for Analysis

VII. Theory

Block 1: Concepts

Unit 1: Agricultural Marketing-

Insights Importance of market analysis in the agricultural system - types of marketing-advantages and disadvantages - quantitative estimation -the distinguishing characteristics and role of agricultural prices -data sources for agricultural products and prices - softwares used in market analysis.

Block 2: Marketing Institutions and Dynamics

Unit 1: Institutions and their functions

Role of various formal institutions in agricultural marketing - and functions - measuring their efficiency - public - private partnership - institutional arrangements. Successful case studies.

Unit 2: Market Dynamics

Multi market estimation, supply response models. Market integration and price transmission - supply / value chain management. GAP analysis. Current trends in information in the changing agrifood system.

Block 3: Techniques

Unit 1: Commodity Marketing

Agricultural commodity marketing -spot and futures- marketing of derivatives-speculation, hedging, swap, arbitrage etc. commodity exchanges - price discovery and risk management in commodity markets-Regulatory mechanism of futures trading.

Unit 2: Models for Analysis

Lag operators and difference equations; stationary and stochastic processes; Unit roots and cointegration; conditional heteroscedasticity: ARCH and GARCH models -forecast evaluation; methods of forecasting. price indices and econometric estimation and simulation.

VIII. Practical

- Estimation of demand/ supply forecasting,
- Supply chain/ value chain analysis for different commodities
- Commodity models- multi market estimation- time series analysis
- Market integration studies- price discovery price volatility estimation
- Commodity price forecasting using econometric softwares.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Suggested Reading

- Acharya SS and Agarawal NL. 1994. *Agricultural Prices-Analysis and Policy*. Oxford and IBH Publishing company Pvt. Ltd, New Delhi.
- Acharya SS and Agarawal NL. 2004. *Agricultural Marketing in India*. Oxford and IBH Publishing company Pvt. Ltd, New Delhi.
- Kohls RH and Joseph N. Uhl: *Marketing of Agricultural products* by Collier MacMillan International.
- Rhodes VJ. 1978. *The Agricultural Marketing System*. Grid Pub. Ohio.

I. Course Title : Quantitative Development Policy Analysis

II. Course Code : AEC 607

III. Credit Hours : 1+1

IV. Why this course?

Policy reforms are inevitable. They are continuously required to deal with the loop holes of previous policy and control the present situation in a better manner. Reforms take place in both microeconomic and macroeconomic polies. The analysis of these policies help us to develop a framework for designing and implementing the policies.

V. Aim of the course

To develop expertise in understanding the rationale behind development of policies. Conceptualization of equilibrium and working out the economic implications of development policy. Learning outcome: After the completion of the course, the student will be able to-Conceptualize policy framework. Get acquainted with analysisng the policy and work out corrective solutions.

VI. Organization of the course

The course is organised as follows

No	Block	Unit
1.	Concepts	1. Policy Framework
2.	Demand-supply and household behaviour	1. Demand- Supply Analysis 2. Household Behaviour and models
3.	Approaches to review policy and welfare	1. Multi-Pronged approach to policy review 2. General equilibrium and programming

Theory

Block 1: Concepts

Unit 1: Policy Framework

olicy framework – goals, value, beliefs and welfare maximization. Market – Policy and State – State vs. Market – Failure of Policy – Failure of Markets - Rationale for Government Intervention. Role of Quantitative Policy Analysis.

Block 2: Demand-supply and household behaviour

Unit 1: Demand- Supply Analysis

Demand analysis for policymaking – Alternative approaches to demand analysis – Policy implications. Supply response – Alternative approaches to measurement of supply response – Nerlovian models of supply response – Policy implications.

Unit 2: Household Behaviour and models

Household behaviour and policy analysis – Household models.

Block 3: Approaches to review policy and welfare

Unit 1: Multi-Pronged approach to policy review

Partial equilibrium analysis – Concept of reference prices – Price distortions – indicators and impact. Transaction costs – Implications for efficiency and productivity – Institutional solutions - Multi market approach to policy analysis.

Unit 2: General equilibrium and programming

Social Accounting Matrices and multipliers -– Computable General Equilibrium models to assess economy wide impact of policy changes. fuzzy goal programming-Compromise programming.

VII. Practical

- Review of criteria for policy evaluation
- Estimation of price elasticities
- Review of estimation of complete demand systems
- Estimation of Nerlovian supply Response model
- Review of Household models
- Specification and estimation of household models
- Partial equilibrium analysis
- Input–output table
- Social Accounting Matrix
- Construction of a SAM
- Computation of Multipliers
- Multi Market Analysis
- Review of Computable General Equilibrium Models.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

I. Course Title : Natural Resource Management

II. Course Code : AEC 608

III. Credit Hours : 1+1

IV. Why this course?

The environment envisages the whole living creatures' within it. There are resources we obtain from the nature and at the same time spoil the environment by exploiting the resources. Thus, it is necessary for the student to develop environment friendly plans to utilize the scarce resources.

V. Aim of the course

Concept building on natural resources. Gaining expertise in economic aspect of natural resources and maintain a balance between economic gains and environment conservation. Learning outcome-After the completion of the course, the student will be able to-Understand the natural resources and methodolies to develop plans for their optimal use. Work out the economics of forest, fisheries and ground water. Be able to deal with the legal matters of the natural resourses.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Concepts	1. Concepts
2.	Models and Management	1. Models for economic view of natural resources 2. Management of water resources
3.	Regulations and planning	1. Property Rights 2. Dynamics of resource economics

VII. Theory

Block 1: Concepts

Unit 1: Concepts

Natural resources - definition - characteristics and classification. Stock dynamics of renewable and non-renewable resources. Equation of motion for renewable and non-renewable resources. Fundamental equation of renewable resources.

Block 2: Models and Management

Unit 1: Models for economic view of natural resources

Growth curves of fishery and forest resources. The role of time preference in natural resource use. Simple two-period model of optimal use of renewable and non-renewable resources. Advanced models of optimal resource use – Static Vs. dynamic efficiency in natural resource use Applications of dynamic programming and optimal control.

Unit 2: Management of water resources

Economics of groundwater use - optimal extraction of groundwater. Analytical and numerical solutions for optimal inter-temporal allocation of natural resources. Optimal harvesting of single rotation and multiple rotation forests. Optimal management of fishery.

Block 3: Regulations and planning

Unit 1: Property Rights

Property rights in natural resources and their implication for conservation and management of natural resources. Management of common property natural resources – Institutional arrangements for conservation and management of common pool fishery, groundwater and forestry resource.

Unit 2: Dynamics of resource economics

Resource scarcity – Natural resource degradation – Poverty and resource degradation

– Natural resource accounting - Pricing and valuation of natural resources – Natural resources policy. Practical Derivation of the fundamental equation of renewable resources-Estimation of growth curves and stock dynamics for fishery and forestry resources. Simple two period problem of optimal resource use – Numerical solution for simple two-period model of dynamic efficiency in natural resource extraction. Multi-period dynamic efficiency – Using Excel Solver in solving dynamic natural resource harvesting problems. Using analytical solution procedures for solving natural resource management problems – Optimal control.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

IX. Suggested Reading

- Hackett SC. 2001. *Environmental and Natural Resource Economics: Theory, Policy and the Sustainable Society*. M.E. Sharpe, Armonk, NY.
- Hartwick JM and Olewiler ND. 1998. *The Economics of Natural Resource Use*. 2nd Ed. Addison-Wesley Educational Publ.
- Kerr JM, Marothia DK, Katar Singh, Ramasamy C and Bentley WR. 1997. *Natural Resource Economics: Theory and Applications in India*. Oxford & IBH.
- Pearce DW and Turner K. 1990. *Economics of Natural Resources and the Environment*. John Hopkins Univ. Press.
- Prato T. 1998. *Natural Resource and Environmental Economics*. Iowa State Univ. Press.
- Sengupta R. 2000. *Ecology and Economy, an Indian Perspective*. Oxford Univ. Press.
- Tietenberg T. 2003. *Environment and Natural Resource Economics*. 6th Ed. Addison Wesley.

I. Course Title : Environmental Economics

II. Course Code : AEC 609

III. Credit Hours : 2+1

IV. Why this course?

Economics not only deals with transaction taking place between human beings within and across national boundaries. Each economic activity has a price to pay to the environment. The activity causes loss to the environment in various ways. Thus, as a student of economics it is necessary to work out the costs and returns in terms of losses to environment while carrying out these development/production activities.

V. Aim of the course

To understand the economic outcomes of environmental degradation. Make students proficient in decision making regarding environment protection, resource use, and conservation policy.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Overview	1. Overview of Environmental Economics
2.	Assessment and Development Dynamics	1. Economic assessment 2. Developmental Aspects

No	Block	Unit
3.	Regulations and Issues	1. Accounting, Policies and Regulations 2. Environmental Issues

VII. Theory

Block 1: Overview

Unit 1: Overview of Environmental Economics

Environmental pollution as a consequence of market failure - Causes and consequences of market failure - Externalities - Public goods and externalities -Economics of pollution – Private vs. Social cost of environmental pollution – Property rights, environment and development – Theory of environmental policy.

Block 2: Assessment and Development Dynamics

Unit 1: Economic assessment

Environmental cost benefit analysis - Environmental impact assessment techniques Non-market valuation of environmental resources (WTP / WTA) - Environment, market and social welfare.

Unit 2: Developmental aspects

Economic growth and environmental cost - Growth oriented economic policies and their environmental impacts - Population and environmental quality - poverty and environmental degradation – Sustainable development – Indicators of sustainable development – Issues in sustainable development.

Block 3: Regulations and Issues

Unit 1: Accounting, Policies and Regulation

Environment, ecology and environmental accounting - Environmental pollution with respect to water and air - Land and forest resources related environmental pollution - Coastal externalities - Urbanization and environment - Basic approaches to environmental policy (Tax, subsidy, pollution permits, *etc.*) Green taxes - Political economy of environmental regulation and management.

Unit 2: Environmental Issues

Transboundary environmental problems - Economics of global warming, climate change and emission trading - Environment, international trade and development.

VIII. Practical

- Contemporary global environmental global environmental issues, movement, policies, programmes, laws and other regulatory mechanisms
- Criteria for evaluating the environment related projects and review of Environmental Impact Assessment (EIA) techniques
- Recreation demand models of environmental valuation
- Contingent valuation techniques
- Environmental Resource Accounting Techniques
- Discussion on the techniques dealing with air pollution and review of case studies on air pollution and its impacts - forest environment and wild life conservation
- Green GDP and Green house insurance
- Practical considerations and comparison of instruments of environmental policy

- Non-point source pollution control methodologies
- Environment in macroeconomic modeling
- Meta-analysis, economic valuation and environmental economics
- Multi-criteria methods for quantitative, qualitative and fuzzy evaluation problems related to environment
- Input output analysis, technology and the environment
- Computable general equilibrium models for environmental economics and policy analysis.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After the successful completion of the course, the student will be able to-Understand the concept of pollution and externalities caused by economic activity. Work out the economics of productions activities in terms of losses to environment. Learn about accounting of environmental costs and other issues related.

XI. Suggested Reading

- Hackett SC. 2001. *Environmental and Natural Resource Economics: Theory, Policy and the Sustainable Society.* ME. Sharpe, Armonk, NY.
- Hartwick JM and Olewiler ND. 1998. The Economics of Natural Resource Use. 2nd Ed. Addison-Wesley Educational Publ.
- Kerr JM, Marothia DK, Katar Singh, Ramasamy C and Bentley WR. 1997. *Natural Resource Economics: Theory and Applications in India.* Oxford & IBH.
- Pearce DW and Turner K. 1990. *Economics of Natural Resources and the Environment.* John Hopkins Univ. Press.
- Prato T. 1998. *Natural Resource and Environmental Economics.* Iowa State University Press.
- Sengupta R. 2000. *Ecology and Economy, an Indian Perspective.* Oxford University Press.
- Tietenberg T. 2003. *Environment and Natural Resource Economics*. 6th Ed. Addison Wesley.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Social Sciences
– Agricultural Extension Education

Acknowledgements

Curriculum reform essentially means bringing about changes to the subject content, delivery, and assessment of a curriculum. In the field of agricultural extension, curriculum reforms are important for several reasons. Firstly, farmers face several new challenges related to changing climate, uncertain markets and deteriorating and declining natural resource which sustain agriculture. These challenges mean that extension today needs to tackle an increased diversity of objectives that not only include but also go beyond transfer of new technology and increasing production. While some of these roles still continue to be important, extension services are required to play an increasingly important intermediation and facilitation role to support application of new knowledge.

Agriculture extension is no longer only a public sector phenomenon. It now involves a more complex range of actors providing a wide range of services, together bracketed as EAS. These include organizations in the private sector dealing with agriculture inputs, agribusiness, and financial services; non-governmental organizations (NGOs) (international as well as local); producer groups, cooperatives and associations; consultants (independent as well as associated with or employed by agri-business/ producer associations) and information and communication technology (ICT)-based services. The job market for extension professionals has thus changed and now demands quite different competencies than what the current curricula tries to provide.

Moreover, the theory and practice of extension has evolved considerably in the recent past based on new research in the area of diffusion, innovation and communication studies. These new insights are important tools in any effort to reinvent extension to meet the evolving needs of stakeholders in the Agricultural Innovation Systems (AIS).

The sub-committee on Agricultural Extension constituted by ICAR (under the ICAR Broad Subject Matter Area (BSMA) for Social Sciences) has kept above development in view while revising the PG and Ph.D. Curricula in Agricultural Extension. We also addressed the issue of repetitions of content at different levels and in this process, and considered the Fifth Dean Committee report and the earlier under-graduate curricula in extension. Moreover, student's prior knowledge is critical for learning any discipline and therefore identified first the core competencies that are required at the different levels and worked backwards based on the areas and organizing them into courses.

We are also recommending internship at the Master's level for 5 credits and Teaching Assistantship at the Ph.D. level for 5 credits. We believe this will help the students to have more relevant practical experience and this will boost their job prospects. The committee also discussed about the need for organizing exposure visit for PG/Ph.D. students to universities abroad (student exchange).

We have organized the curricula under different block and units and each course has an introduction explicitly stating the purpose of this course (why this course?), aim of the course (what it tries to provide?) and learning outcomes. Several new and relevant references including appropriate web links to different resources are also provided at the end of each course. The committee strongly proposes training programmes in collaboration with the

concerned organizations for the teachers of Agrl Extension of all SAUs to gear them up for dealing the new revised courses effectively.

The report is based on several rounds of stakeholders meeting and consultation with extension professionals representing different universities, ICAR institutions, NGOs etc. involved in teaching and training in extension . The first such workshop was at Hyderabad on 12 July 2018. Our sincere thanks to Dr R.K. Samantha, Former VC, BCKV, Mohanpur, West Bengal; Dr Raji Reddy, Director of Extension, PJTSAU, Hyderbabad; Dr Biswanath Sadangi, Former Head, ICAR-CIWA, Bhubaneswar; Dr Mahesh Chander, Head, Division of Extension Education, ICAR-IVRI, Izatnagar; Dr Debabrata Basu, Porfessor and HoD, BCKV, Nadia; Dr R.N. Padaria, Principal Scientist (Extension) IARI, New Delhi; Dr K. Ponnusamy, Principal Scientist, NDRI, Karnal; Dr Sreenath Dixit, Head, ICRISAT; Dr Basavaprabhu Jirli, Professor (Extension), I.A.S, BHU, Varanasi; Dr D. Sandhya Shenoy, Principal Scientist (Extension), ICAR-NAARM, Hyderbabad; Dr Bharat S. Sontaki, Principal Scientist, ICAR-NAARM, Hyderbabad; Dr Rasheed Sulaiman, Director, CRISP, Hyderbabad; Dr Sarvanan Raj, Director (Agriculture Extension), MANAGE, Hyderbabad; Dr P.V.K. Sasidhar, Professor and Director, SOEDS, IGNOU, New Delhi; Dr P. Amala Kumari, Professor (Retd.), College of Home Science, Hyderbabad; Dr Srinivas Surisetti, Professor, TISS, Hyderbabad; Dr V. Sudha Rani, Professor and Head, Dr G. Samuel, Professor, Dr A. Sailaja, Professor, Dr M. Sreenivasulu, Professor, Ms Aruna, Assistant Professor from the Department of Agricultural Extension, College of Agriculture, Hyderbabad; Prof. K. Madhu Babu, Director, Prof. B. Jamuna, Prof. S. Chandra Shekar, Prof. R. Vasantha. Prof. M.Preethi, Prof. M. Prasuna, Extension Education Institute, Hyderbabad; Prof. Ch. Venugopal Reddy, PAIO; Dr V. Ravinder Naik, Senior Scientist, Agricultural Information and Communication Centre, PJTSAU, Hyderbabad; Dr P. Prashanth, Scientist, Electronic wing, PJTSAU, Hyderbabad; Dr B. Savitha, Assistant Director of Extension, PJTSAU, Hyderbabad; Dr P. Archana, Scientist (ToT), DAATTC, Mahboobnagar, Dr K. Madan Mohan Reddy, Scientist (ToT), DAATTC, Karimnagar, Dr R. Vishwatej, S.M.S (Agriculture Extension), KVK, Bhadradri, Kothagudem for their valuable inputs which paved way for right direction to identify the lacunae in the existing curricula and to prepare the revised curricula.

The committee also interacted closely with the Sub-Committee constituted by the National Institute of Agricultural Extension Management (MANAGE) for development of Extension curricula and this joint effort of two committees represents a much wider number of extension professionals.

Our special thanks to Ms V. Usha Rani, IAS, Director General, MANAGE and all the sub-committee members of MANAGE Sub-Committte on Extension Curricula Reforms (Dr Saravanan Raj, MANAGE, Dr Rasheed Sulaiman, CRISP-AESA, Dr P.S. Sivakumar, ICAR-CTCRI, Dr Mahesh Chander, ICAR-IVRI, Dr M. Chandragowda, ICAR-ATARI, Dr M.A. Ansari, GBPUAT, Dr P.V.K. Sasidhar, IGNOU, Dr P.S. Ananthan, ICAR-CIFE, Dr Ritu Chakravarty, ICAR-NDRI, Dr Sagar Wadkar, VAMNICOM and Dr Souvik Ghosh, Visva Bharati University) for their specific contributions to development of this revised curricula. The two days joint consultation and brain storming on each of the courses, the two committees organized together at Hyderabad on 28-29 September 2018 helped us in development of this final output. Our special thanks to Dr Onima, V.T., Research Officer, Centre for Research on Innovation and Science Policy (CRISP) for supporting this exercise both intellectually and operationally.

The committee organized third BSMA (Social Sciences) meeting on 28-01-2019 at Institute of Agricultural Sciences, BHU, Varanasi for reviewing the final drafts of three

disciplines of social Sciences. Our sincere thanks to Dr Basavaprabhu Jirli, Professor and Head, Prof. A.K. Singh and Prof. Kalyan Ghadee from the Department of Extension Education, I.A.S, BHU, Varanasi for their critical comments and suggestions with regard to revised curricula.

The suggestions at National Core Group review on April 24, 2019 were valuable and incorporated in the report. The detailed insights and advice from Dr N.S. Rathore as Chairman of the Special Meeting of BSMA on May 10, 2019 were crucial in shaping of final report.

Our sincere gratitude and thanks to all the members of BSMA Committee for Social Sciences namely Dr Rakesh Singh, Professor, Dept. of Agricultural Economics, IAS, BHU, Varanasi, Dr S. Mahapatra, Professor and Head, Agri Business Management, OUAT, Bhubaneswar, and Dr Aditi Mathur, Professor, Institute of Agri Business Management, Swami Keshwanand Rajasthan Agricultural University, Bikaner for their continuous support, encouragement and suggestive nature throughout the journey of final draft preparation.

Our sincere and heartfelt thanks to Dr V. Praveen Rao, Hon'ble Vice Chancellor, PJTS AU, Rajendranagar, Hyderabad for permitting the committee to conduct the national level stakeholders meeting in the University on 20th July 2018. Our special thanks to Dr S. Sudheer Kumar, Registrar and Dr D. Raji Reddy, Director of Extension, PJTSAU for their unstinted support and cooperation to the BSMA committee.

Finally, we thank profusely Dr N.S. Rathore, Former Deputy Director General (Education), and Dr R.C. Agrawal, Current Deputy Director General (Education) ICAR, New Delhi for constituting the BSMA for undertaking curricula revision of PG and Ph.D. in Social Sciences and for their valuable guidance and support in this regard.

I. Sreenivasa Rao
(Member, BSMA, Agricultural Extension)
Dr Lipi Das
(Convener, BSMA, Social Sciences)
Dr Kalpana Sastry
(Chairperson, BSMA, Social Sciences)

September, 2020

Preamble

Justification for modification of Present Courses and recommendation of New Courses Innovativeness in the present curricula development:

- The developed curricula is the result of sincere and coordinated effort of multi-stakeholders and experts in the discipline of Extension Education with a aim to enhance the value of the discipline, relevance to field and develop the graduates with multi core competencies to face the challenges in TOT.
- The content of the courses are perfectly related to the present changes and scenario in the Ecosystem of Extension Education at National and Global level.
- The practical content coverage will give multiple opportunities to the graduates to have hands on experience and demonstrate what they learn in variety of contexts i.e. various extension teaching methods, Big data, IOTs, project development and evaluation, organizations of groups/FPOs, etc.
- The recommended curricula is perfect match and having high relevancy to the developments and innovations in the field.
- The curricula is developed by benchmarking the core competencies that are expected from the Extension graduates, thus the approach is bottom-up.
- The recommended Extension Research methodology courses will help the students to identify the contemporary problems and their solving could lead to develop quality extension models for effective TOT and policy making.
- The recommended Internships and Teaching assistantships will help the students to have more relevant practical experience and this will boost their job prospects.

Course Title with Credit Load
M.Sc. in Agricultural Extension Education

Major Courses 20

Course Code	Course Title	Credit Hours
EXT-501*	Extension Landscape	2(2+0)
EXT-502*	Applied Behaviour Change	3(2+1)
EXT-503*	Organisational Behaviour and Development	3(2+1)
EXT-504*	Research Methodology in Extension	3(2+1)
EXT-505*	Capacity Development	3(2+1)
EXT-506*	ICTs for Agricultural Extension and Advisory Services	3(2+1)
EXT-507*	Evaluation and Impact Assessment	3(2+1)

Minor Courses 08

a. It is suggested the student may choose at least two out of three courses listed below as part of minor courses as these are related to policy advocacy and aim to build larger understanding of the subject.
b. Further, it is suggested that the student may choose the remaining Courses from any other discipline including the disciplines of Agrl. Economics/ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/HoD.

EXT-508	Managing Extension Organisations	3(2+1)
EXT-509	Enabling Innovation	2(1+1)
EXT-510	Gender Mainstreaming	3(2+1)

Supporting Courses 06

STAT	Statistical Methods for Applied/ Social Sciences	3(2+1)
STAT/COMP	Computer Applications for Agricultural Extension Research	3(2+1)

It is suggested that the student may choose the Supporting Courses other than the listed courses, provided the opted courses are related to the research problem selected by the student and be mandatorily approved by the Student Advisory committee/HoD".

Common Courses 05

1. Technical Writing and Communications Skills
2. Intellectual Property and its management in Agriculture
3. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on

SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the HoD/BoS.

EXT-591	Master's Seminar	**01**
	Thesis/Research	30
	Total	70

Course Contents
M.Sc. in Agricultural Extension Education

I. Course Title : Extension Landscape
II. Course Code : EXT 501
III. Credit Hours : 2+0

IV. Why this course?

Extension and advisory services (EAS) need to support farmers to deal with several new challenges they face currently. To effectively support farmers, EAS should perform several new functions and it should have capacities to perform these functions. EAS have evolved considerably especially during the last 3 decades. Several new approaches have emerged and many new funding and delivery models emerged in response to reforms (economic policies and new governance structure) implemented in several countries. Apart from these, new insights from communication and innovation studies have also started to influence the practice of extension. There is a lot of interest globally in strengthening pluralistic EAS and enhancing its contribution towards development of an effective Agricultural Innovation System (AIS). Keeping these in view, there is a need to orient students of extension on how extension is shaped globally and the policy level challenges it faces so that the extension students fit well to the global demand for competent extension professionals who can appreciate and understand this changing context.

V. Aim of the course

The aim of this course is to introduce the new challenges before extension and how extension is evolving globally. It presents the new capacities that are needed by EAS providers to provide a much wider support to farmers and it orient students to the new insights from communication and innovation studies that are influencing the practice of extension globally. The course also help students to appreciate the process and the impact of extension reforms implemented in many countries, the new approaches that are evolving globally in different regions and the policy challenges in managing a pluralistic extension system.
The course is organized as follows:

No	Blocks	Units
1	Globally, What is new in Extension?	1. Challenges Before Extension and Advisory Services 2. New Functions and New Capacities 3. Pluralism in EAS
2.	Insights from Communication & Innovation Studies & New Extension Approaches	1. From the Linear Paradigm To Systems Paradigm 2. Evolving Extension Approaches
3	Extension Reforms And Policy Challenges	1. Changes In Governance, Funding and Delivery of EAS 2. Challenges In Managing Pluralistic EAS

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the changing global extension landscape
- Broaden their understanding on the role of EAS in agricultural innovation system
- Critically evaluate the reforms in extension and the evolving approaches in extension
- Analyse the policy level challenges in extension funding and delivery

Block 1: Globally, What Is New In Extension?

Unit 1: Challenges before Extension and Advisory Services (EAS)

Extension and Advisory Services (EAS)- Meaning (embracing pluralism and new functions) New Challenges before farmers and extension professionals: Natural Resource Management-Supporting farmers to manage the declining/deteriorating water and soil for farming; Gender Mainstreaming- How extension can enhance access to new knowledge among women farmers; Nutrition- Role of extension in supporting communities with growing nutritious crop and eating healthy food; Linking farmers to markets- Value chain extension including organizing farmers, strengthen value chain and supporting farmers to respond to new standards and regulations in agri-food systems; Adaptation to climate changes-How extension can contribute to up-scaling Climate Smart Agriculture; Supporting family farms-strengthening the capacities of family farms; Migration-Advising farmers to better respond to opportunities that emerge from increasing mobility and also supporting migrants in enhancing their knowledge and skills; Attracting and Retaining Youth in Agriculture including promotion of agripreneurship and agri-tourism; Urban and peri-urban farming- How to support and address issues associated with urban and peri-urban agriculture; Farmer distress, suicides- Supporting farmers in tackling farm distress.

Unit 2: New Functions and New Capacities

Beyond transfer of technology: Performing new functions to deal with new challenges; Organising producers into groups-dealing with problems that need collective decision making such as Natural Resource Management (NRM) and access to markets; Mediating conflicts and building consensus to strengthen collective decision making; Facilitating access to credit, inputs and services-including development of service providers; Influencing policies to promote new knowledge at a scale Networking and partnership development including convening multi-stakeholder platforms/ innovation platforms.

New Capacities needed by extension and advisory services at different levels –at the individual (lower, middle management and senior management levels), organizational and enabling environment levels; –Core competencies at the individual level; Varied mechanisms for capacity development (beyond training).

Unit 3: Pluralism in EAS

Pluralism in Extension Delivery: Role of private sector (input firms, agri-business companies, consultant firms and individual consultants)- Trends in the development of private extension and advisory services in India and other countries; challenges faced by private extension providers; Role of Non-Governmental Organizations (National/international)/ Civil Society Organizations (CSOs) in providing extension-Experiences from India and other countries; Producer Organizations- Role in strengthening demand and supply of extension services; their strength and weaknesses-experiences from different sectors; Role of Media and ICT advisory service providers; global experiences with use of media and ICTs in advisory services provision.

Block 2: Insights From Innovation Studies and New Extension Approaches

Unit 1: From the Linear Paradigm to Systems Paradigm

Diffusion of Innovations paradigm- strengths and limitations; multiple sources of innovation-farmer innovation, institutional innovation; farmer participation in technology generation and promotion; strength and limitations; Agricultural Knowledge and Information Systems (AKIS); strength and limitations; Agricultural Innovation Systems (AIS); Redefining Innovation- Role of Extension and Advisory Services in AIS-From information delivery to intermediation across multiple nodes; Role of brokering; Innovation Platforms, Innovation Management; Strength and weaknesses of AIS. Rethinking Communication in the Innovation Process – Network building, support social learning, dealing with dynamics of power and conflict.

Unit 2: Evolving Extension Approaches

Evolution and features of extension approaches: Transfer of technology approach; educational approach, farmer participatory extension approach, demand-driven extension, market led extension (value chain extension), extension for climate smart agriculture, gender sensitive extension, extension for entrepreneurship Extension systems in different regions: Asia-Pacific, Europe, Latin America, Australia, North America Networking for Strengthening EAS: GFRAS (Global Forum for Rural Advisory Services) and its regional networks.

Block 3: Extension Reforms and Policy Challenges

Unit 1: Changes in Governance, Funding and Delivery

Reduction in public funding: public withdrawal from extension provision (partial/ full); Examples/Cases; Privatization: Public funding and private delivery; cost sharing and cost recovery; Examples/Cases; Decentralisation of extension services; Examples/ Cases; Lessons from extension reforms in different countries; Extension and Sustainable Development Goals (SDGs).

Unit 2: Challenges in Managing Pluralistic Extension Systems

Pluralism: Managing pluralism and Co-ordination of pluralistic extension provision; Public private partnerships in extension (including the role of local governments/ panchayats and producer organisations); Examples, challenges in co-ordination; Achieving convergence in extension planning and delivery, Financing Extension: Mobilising resources for extension: public investments, donor support (grants/loans); Monitoring and Evaluation of Extension: Generating appropriate data for Assessment and Evaluation of pluralistic extension; Strengthening extension policy interface; generating evidence on impact of extension and policy relevant communication.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Book Review by students
- Student presentation
- Group Work

VIII. Suggested Reading

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David S. 2018. *Migration and rural advisory services*. GFRAS Issues Paper 2. Global Forum for Rural Advisory Services. https://www.g-fras.org/en/knowledge/gfras-publications/category/97-gfras-issues-papers.html?download=856: migration-and-rural-advisory-services

Davis K and Heemskerk W. 2012. *Coordination and Collective Action for Agricultural Innovation* Overview Module 1 Investment in Extension and Advisory Services as Part of Agricultural Innovation Systems. In Agricultural Innovation Systems: An Investment Sourcebook. Agricultural and Rural Development. World Bank. © World Bank. http://siteresources.worldbank.org/INTARD/Resources/335807-1330620492317/9780821386842ch3.pdf

FAO. 2016. *New directions for inclusive Pluralistic Service Systems*. Report of FAO Expert Consultation. Food and Agriculture Organization of the United Nations and Royal Tropical Institute, Rome. http://www.fao.org/3/ai6103e.pdf

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Rao S. 2015. *Using Radio in Agricultural Extension*. Note 18. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://www.g-fras.org/en/good-practice-notes/using-radio-in-agricultural-extension.html#SNote8

Rivera W and Zijp W. 2002. *Contracting for Agricultural Extension-International Case Studies and Emerging Practices*. CABI Publishing.

Saravanan R and Suchiradipta B. 2015. *mExtension – Mobile Phones for Agricultural Advisory Services*. Note 17. Gfras good practice note for extension and advisory services. GFRAS: Lindau, Switzerland.
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- **AESA**- Agricultural Extension in South Asia http://www.aesanetwork.org/
- **FAO**- Food and Agricultural Organisation (Research and Extension) http://www.fao.org/research-and-extension/en/
- **GFRAS**- Global Forum for Rural Advisory Services http://www.g-fras.org/en/
- **INGENEAS**- Integrating Gender and Nutrition within Agricultural Extension Services https://ingenaes.illinois.edu/
- **IFPRI**- International Food Policy Research Institute (Extension) http://www.ifpri.org/topic/agricultural-extension
- **KIT**- Royal Tropical Institute (KIT)-Sustainable Economic Development https://www.kit.nl/sed/
- **WUR**- Wageningen University and Research Research (Knowledge, Technology and Innovation Group (KTI)) https://www.wur.nl/en/Research-Results/Chair-groups/Social-Sciences/KnowledgeTechnology-and-Innovation-Group.htm

I. Course Title : Applied Behaviour Change

II. Course Code : EXT 502

III. Credit Hours : 2+1

IV. Why this course?

The behavioural change of the stakeholders is the key objective in extension profession, which is reflected through their enhanced capacity, attitude change, modification of perceptions and beliefs, improved understanding of a system, adoption of improved technologies, empowerment, and resilience to adverse phenomenon and improved decision-making. Irrespective of their role and profession, all the key stakeholders in agriculture like farmers, extension agents, scientists/ academicians, development managers and policy makers are human beings, whose behaviour is the product of internal psychological processes influenced by external environment. Since human behaviour is a psychological phenomenon, expressed through interaction of internal psychological processes, social systems and external environment, there is an essential need to understand how these psychological processes guide the behavioural change. These psychological processes may be expressed at individual, group, community and organisational level involving human learning, choices, judgement and decisions about an extension intervention.

V. Aim of the course

This course aims to build capacities of students to understand the fundamental psychological processes which guide human behaviour at individual, group and community levels in specific contexts, to develop sound extension strategies.

The course is organized as follows:

No	Blocks	Units
1	Foundations of Behaviour Change	1. Foundations of Human Behaviour
2	Cognitive Processes and Learning	1. Cognitive Processes affecting Human Behaviour 2. Information Processing 3. Learning 4. Judgement, Choice and Decision-making
3	Human Behaviour in the Society	1. Attitudes and Influence 2. Social Judgement, Social Identity and Inter-Group Relations

VI. Theory

Block 1: Foundations of Behaviour Change

Unit 1: Foundations of Human Behaviour

Human behaviour – Meaning, importance and factors influencing human behaviour; Biological bases of human behaviour – Nervous system, brain, endocrine system and genes; Individual variations – intelligence, ability and creativity– foundations and theories, personality and temperament - foundations, approaches, theories of personality, measuring personality (traits, locus of control, self-efficacy; Personal, social and moral development – meaning, concepts – self-concept, self-esteem and self-worth and theories. Motivation – foundations, approaches, theories, managing human needs and motivations; perceiving others – impression, attitude, opinions; Emotions - foundations, types and functions, measuring emotional intelligence.

Block 2: Cognitive Processes And Learning

Unit 1: Cognitive Processes affecting Human Behaviour

Sensory organs and their role cognition; Cognitive processes – Attention, perception, remembering and forgetting, knowledge and expertise – foundations and theories; Principles and processes of perception; Consciousness – meaning, types, sleep and dreams; Learning and Memory – Memory - meaning, types and mechanisms of storage and retrieval of memories in the Human brain; Complex cognitive processes - Concept formation, Thinking, Problem solving and transfer – foundations, theories and approaches.

Unit 2: Information Processing

Information processing – meaning, principles; Models of information processing - Waugh and Norman model of primary and secondary memory; Atkinson and Shiffrin's stage model of memory; other models including blooms taxonomy and Sternberg's Information Processing Approach; Attention and perception – meaning, types, theories and models; Consciousness.

Unit 3: Learning

Learning – foundations, approaches and theories; Cognitive approaches of learning – meaning, principles theories and models; Memory – foundations, types; Behavioural approaches of learning – foundations and theories - classical conditioning, operant conditioning, applied behaviour analysis; Social cognitive and constructivist approaches to learning – foundations and theories – social cognitive theory, Self-regulated learning; learning styles – meaning, types and applications in learning.

Unit 4: Judgement, Choice and Decision-making

Human judgement – meaning, nature, randomness of situations, theories and models; Choice – meaning, criteria for evaluating options; theories and models of human choice; Choice architecture; Decision-making – Meaning, problem analysis; steps and techniques of decision-making under different contexts.

Block 3: Human Behaviour in the Society

Unit 1: Attitudes and Influence

Attitudes - meaning, assumptions, types, theories and models of attitude formation; methods of changing attitudes, Relating to others - liking, attraction, helping behaviour, prejudice, discrimination and aggression; Liking/ affect – meaning, types and theories; Attraction – meaning, types and theories; Persuasion – meaning, theories and techniques; Social influence and groups – conformity, compliance and obedience.

Unit 2: Social Judgement, Social Identity and Inter-Group Relations

Social judgement – meaning, frame of reference, stereotyping; The judgement of attitude models; Attribution – meaning, theories; Rational decision making; Social identify – meaning, types; assessment; Groups – meaning, types, group processes; sustainability of groups; Inter group processes and theories social learning.

VII. Practicals

- Understanding perception – Attentional Blink and Repetition Blindness exercise
- Understanding attention - Testing selective attention capacity and skills and processing speed ability through Stroop test
- Hands-on experience in the techniques for assessing creative thinking – divergent and convergent thinking
- Lab exercise in applying Maslow's need hierarchy to assess motivation
- Learning - Classical conditioning and operant conditioning
- Assessing learning styles through Barsch and Kolb inventories
- Practical experience in building self-esteem
- Assessment of emotional intelligence

- Exercises in problem solving
- Exercises in visual perception
- Measuring self-concept using psychometric tools
- Experiment on factors influencing information processing
- Assessment of attitudes
- Hands on experience in methods of persuasion
- Field experience in assessing social judgement
- Simulation exercise to understand decision-making under different situations
- Exercise in rational decision-making.

Teaching methods/activities

– Lecture cum discussion
– Class exercises
– Group Presentation

Learning outcome

The students should:

- Understand the biological and cognitive processes determining human behaviour
- Understand the process of learning under different context
- Develop competencies in influencing the human decision process in various contexts
- Design effective strategies to influence attitude and behaviour

Suggested Reading

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Eysenck MW and Keane M T. 2010. *Cognitive psychology: A student's handbook*. Sixth Edition, Hove: Psychology Press.

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I. Course Title : Organisational Behavior and Development

II. Course Code : EXT 503

III. Credit Hours : 2+1

IV. Why this course?

In changing and competitive world, the survival of any organization is dependent on its ability to adjust to the new challenges, adapt its structure and develop the competencies needed among its staff. This course is designed to understand the theory and practice relating to the processes of organizational behavior, development and change. It attempts to bring about change in the different levels of the organization (the individual, group and organization) using a wide variety of interventions.

V. Aim of the course

- To understand the theory and practice relating to the processes of organizational behavior, development and change.
- To develop insight and competence in diagnostic and intervention processes and

skills for initiating and facilitating change in organizations.
- To gain necessary self-insight, skills in facilitation, organizational development (OD) skills, group process and techniques, to become an effective change agents and OD consultants.
- To understand the behavior of individuals and small groups in organization with special focus on beliefs, attitudes and values, human inference - attribution, self-concept, motivation, active listening, interpersonal communication, conflicts management.

The course is organized as follows:

No	Blocks	Units
1.	Organisational Behaviour	1. Basics of Organisation 2. Basics of Organisational Behaviour 3. Individual Behaviour in Organizations 4. Group Behaviour in Organizations 5. Productive Behaviour and Occupational Stress 6. Organisational Systems
2.	Organisational Development	1. Overview of Organisational Development 2. Managing the Organisational Development Process 3. Organisational Development Interventions 4. Organisational Development Practitioner or Consultant

VI. Theory

Block 1: Organizational Behavior

Unit 1: Basics of Organization

Introduction to organizations-concept and characteristics of organizations; Typology of organizations; Theories of organizations: nature of organizational theory, Classical theories, Modern management theories, System Theory - Criticisms and lessons learnt/ analysis.

Unit 2: Basics of Organizational Behaviour

Concepts of Organisational Behaviour, Scope, Importance, Models of OB.

Unit 3: Individual Behaviour in Organizations

Introduction, Self-awareness, Perception and Attribution, Learning, Systems approach to studying organization needs and motives – attitude, values and ethical behavior, Personality, **Motivation**-Concept & Theories, Managing motivation in organizations.

Unit 4: Group Behaviour in Organization

Foundations of group, group behaviour and group dynamics, Group Development and Cohesiveness, Group Performance and Decision Making, Intergroup Relations; Teams in Organizations-Team building experiential exercises, Interpersonal Communication and Group; Leadership: Meaning, types, Theories and Perspectives on Effective Leadership, Power and Influence, managing Conflict and Negotiation skills, Job/ stress management, decision-making, problem-solving techniques.

Unit 5: Productive Behaviour and Occupational Stress

Productive behaviour - Meaning, dimension; Job analysis and Job performance – meaning, dimensions, determinants and measurement; Job satisfaction and organizational commitment - meaning, dimensions and measures roles and role clarity; Occupational stress – meaning, sources, theories and models, effects, coping mechanism, effects and management; Occupational stress in farming, farmer groups/ organizations, research and extension organizations.

Unit 6: Organizational System

Organizations Structure- Need and Types, Line & staff, functional, committee, project structure organizations, centralization &decentralization, Different stages of growth and designing the organizational structure; Organizational Design-Parameters of Organizational Design, Organization and Environment, Organizational Strategy, Organization and Technology, Power and Conflicts in Organizations, Organizational Decision-Making; Organizational Culture vs Climate; Organizational Change; Organizational Learning and Transformation.

Block 2: Organisational Development

Unit 1: Overview of Organizational Development

Concept of OD, Importance and Characteristics, Objectives of OD, History and Evolution of OD, Implications of OD Values.

Unit 2: Managing the Organizational Development Process

Basic Component of OD Program-Diagnosis-contracting and diagnosing the problem, Diagnostic models, open systems, individual level group level and organizational level diagnosis; Action-collection and analysis for diagnostic information, feeding back the diagnosed information and interventions; Program Management- entering OD relationship, contracting, diagnosis, feedback, planned change, intervention, evaluation.

Unit 3: Organizational Development Interventions

Meaning, Importance, Characteristics of Organization development Interventions, Classification of OD Interventions-Interpersonal interventions, Team Interventions, Structural Interventions, Comprehensive Interventions.

Unit 4: Organizational Development Practitioner or Consultant

Who is OD consultant? Types of OD consultants and their advantages, qualifications, Comparison of traditional consultants Vs. OD consultants, Organizational Development process by the practitioners skills and activities.

VII. Practicals

- Case Analysis of organization in terms of process – attitudes and values, motivation, leadership.
- Simulation exercises on problem-solving – study of organizational climate in different organizations.
- Study of organizational structure of development departments, study of departmentalization, span of control, delegation of authority, decision-making patterns.
- Study of individual and group behaviour at work in an organization.
- Conflicts and their management in an organization.

- Comparative study of functional and nonfunctional organizations and drawing factors for organizational effectiveness.
- Exercise on OD interventions (Interpersonal, Team, Structural, Comprehensive) with its procedure to conduct in an organization

VIII. Teaching methods/activities

- Lecture cum discussion
- Cases
- Class exercises
- Group Presentation

IX. Learning outcome

This course will equip the students to become potential change agents and OD practitioners. They should be able to learn how to improve individual, group/team and organizational performance through the use of OD techniques or interventions.

X. Suggested Reading

Bhattacharyya DK. 2011. *Organizational Change and Development*, Oxford University Press.

Hellriegel D, Sloccum JW and Woodman. 2001. **Organizational Behaviour.** Cincinnati, Ohio: South-Western College Pub.

Luthans F. 2002. *Organizational Behaviour*. Tata McGraw-Hill, New York

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Shukla, Madhukar. 1996. *Understanding Organizations*. Prentice Hall of India, New Delhi.

Stephens PR and Timothy AJ. 2006. *Organizational Behaviour*, 12th Edition. Prentice Hall Pub.

Thomas GC and Christopher GW. 2013. *Organizational development and change*, 10th edition, South-Western college publishing.

Wendell LF and Cecil HB. 1999. *Organizational Development: Behavioural science interventions for organization improvement*, Pearson. 368 pp.

I. Course Title : Research Methodology in Extension

II. Course Code : EXT 504

III. Credit Hours : 2+1

IV. Why this course?

Growth of any discipline is directly proportional to the creation of knowledge in that discipline. Extension research is the backbone of extension discipline. Extension research is a unique social science inquiry where research ideas are gathered from the field problems and put through a systematic cycle of objective investigations that result in significant solutions. Apart from developing theories and models that advance scientific knowledge, extension research should also provide new insights for improving extension policy and practice. As extension is a field oriented discipline seeking to improve the welfare of its stakeholders, the extension professionals require critical competencies in conducting empirical research for developing sound extension models, methods and tools.

V. Aim of the course

This course aimed to create a workforce which has sound fundamental knowledge and critical competencies in planning, conducting and applying behavioural research for developing quality extension models, methods and tools.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to behavioural research	1. Nature of Behavioural Research 2. The Behavioural Research Process
2.	Steps in behavioural research process	1. Formulating a Research Problem 2. Reviewing the Literature 3. Identifying Variables and Hypotheses 4. Formulating Research Designs, Methods and Tools 5. Selecting Sample 6. Collecting Data 7. Analysing and Interpreting the Data 8. Reporting and Evaluating Research

VI. Theory

Block 1: Introduction To Behavioural Research

Unit 1: Nature of Behavioural Research

Methods of knowing; Science and scientific method; Behavioural research – Concept, aim, goals and objectives; Characteristics and Paradigms of research; Types of behavioural research based on applications, objectives and inquiry; Types of knowledge generated through research – historical, axiological, theoretical and conceptual knowledge, prior research studies, reviews and academic debate; Role of behavioural research in extension; Careers in behavioural research.

Unit 2: The Behavioural Research Process

Basic steps in behavioural research – Formulating a Research Problem; Reviewing the Literature; Identifying the variables and hypotheses; Formulating research designs, methods and tools; Selecting sample; Collecting data; Analyzing and Interpreting the Data; Reporting and Evaluating Research; Skills needed to design and conduct research; Writing research proposals.

Block 2: Steps in Behavioural Research Process

Unit 1: Formulating a Research Problem

The research problem and research topic - definitions; Importance of formulating a research problem; Sources of research problems; Characteristics of a good research problem; Research problems in quantitative and qualitative research; Steps in formulating a research problem; Strategies for writing research problem statement; Research purpose statement; Research questions – Types, Criteria for selecting research questions, techniques for narrowing a problem into a research question; Objectives - Meaning, types and criteria for judging the objectives.

Unit 2: Reviewing the Literature

Review-meaning and importance; Types of literature review – Context, Historical, Integrative, methodological, self-study and theoretical; Literature review for quantitative and qualitative studies; Steps in conducting literature review – Identify key terms, locate literature, critical evaluation and selection; organising literature and writing literature review.

Unit 3: Identifying Variables and Hypotheses

Developing theoretical, conceptual, empirical frameworks; Approaches for identifying concepts, constructs and variables; Role of theory in behavioural research; Steps in identifying variables – Domain, Concepts, Constructs, Dimensions; Indicators; Variables, Definitions, premises, propositions and hypotheses; Techniques of identifying concepts, constructs and variables - Types of concepts; Types of variables –causal relationship, the study design; and the unit of measurement; Types of definitions-Types of propositions and hypotheses. Characteristics of good hypotheses; Measurement – Meaning, levels of measurement – nominal, ordinal, interval and ratio; Criteria for choosing measurement levels for variables.

Unit 4: Formulating Research Designs, Methods and Tools

Research designs – Definition, purpose and functions; Research Design as Variance Control - MAXMINCON Principle; Criteria for selecting a suitable Research Design; Classification of research designs: Quantitative designs - experimental, descriptive, comparative, correlational, survey, ex-post facto and secondary data analysis; Qualitative designs - ethnographic, grounded theory, phenomenological and Narrative research; Mixed method designs – Action research design; Translational research; Elements of research design - Research strategies, Extent of researcher interference, Study setting, Unit of analysis and Time horizon. Sources of errors while specifying research designs. Internal and external validity; Choosing right research design; Triangulation - Importance in behavioural research, Types of triangulation. Research methods: Designing research Instruments – questionnaires, interview schedules; tests – knowledge tests, behaviour performance tests; scales – scales and indexes, checklists, focus groups; Steps in developing and using research methods and tools; participatory rural appraisal.

Unit 5: Selecting Sample

Sampling - population, element, sample, sampling unit, and subject; Sampling strategies for quantitative and qualitative research; Principles of sampling; Factors affecting the inferences drawn from a sample; Types of sampling, Methods of drawing a random sample, Sampling with or without replacement, Types of sampling - Probability Sampling - Simple random sampling, Cluster sampling, Systematic sampling, Stratified random sampling and Unequal probability Sampling; Non-probability Sampling - Reliance of available subjects, Purposive or judgmental sampling, accidental sampling, expert sampling, Snowball sampling, and Quota sampling; Sample size requirements for quantitative and qualitative studies. Methods for estimating sample size; Generalisation – Importance, Types of generalisations.

Unit 6: Collecting Data

The process of collecting data – Selection, training, supervision, and evaluation of field investigators; Online data collection; Errors and biases during data collection. Testing goodness of measures through item analysis - Reliability and validity; Types of validity – Content validity: Face and content validity, Criterion-related validity: concurrent and predictive validity, Construct validity: convergent, and discriminant validity, factorial validity, and nomological validity; Types of reliability – Test-Retest, Parallel forms, Inter-item consistency reliability, Split-half reliability.

Factors affecting the validity and reliability of research instruments, Strategies for enhancing validity and reliability of measures. Validity and reliability in qualitative research.

Unit 7: Analyzing and Interpreting the Data

Data coding, exploration and editing; Methods of data processing in quantitative and qualitative studies; Quantitative data analysis - parametric and non-parametric statistical analyses; Parametric analysis – Descriptive and inferential statistics, Hypothesis testing - Type I and Type II errors. Concepts in hypothesis testing - Effect Size, á, â, and Power, P Value; Multivariate data analysis – regression, factor analysis, cluster analysis, logistic regression and structural equation modelling. Guidelines for choosing appropriate statistical analysis; Statistical packages for data analysis; Methods of interpreting data and drawing inferences - The Ladder of Inference; Methods of communicating and displaying analysed data.

Unit 8: Reporting and Evaluating Research

Writing reports and research publications; Evaluation Methodology

VII. Practicals

- Selecting a research problem and writing problem statement
- Narrowing down research problem to purpose, research questions and objectives
- Choosing, evaluating and reviewing research literature
- Selection of variables through construct conceptualisation and defining variables
- Choosing research design based on research problem
- Choosing right sampling method and estimating sample size
- Developing research methods and tools – questionnaires, interview schedule, check lists and focus group guides
- Writing a research proposal
- Field data collection using research methods and tools
- Testing reliability and validity of research instruments
- Hands on experience in using SPSS for coding, data exploration, editing, analysis and interpretation Formulation of secondary tables based on objectives of research
- Writing report, writing of thesis and research articles
- Presentation of reports

VIII. Teaching methods/activities

– Lecture cum discussion
– Class exercises
– Assignment(Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Research Report

IX. Learning outcome

– Understand the concepts, paradigms, approaches and strategies of behavioural research
– Enable to choose research design, methods and tools suitable for the research problem
– Design research instruments skilfully and conduct research in an objective and unbiased way

– Analyse the data through appropriate analytical methods and tools and derive meaningful interpretations

X. Suggested Reading

Babbie E. 2008. *The basics of social research*. 4th ed. Belmont, CA, USA; Thompson Wordsworth.

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Sivakumar PS and Sulaiman RV. 2015. *Extension Research in India-Current Status and Future Strategies*. AESA Working Paper 2. Agricultural Extension in South Asia.http://www.aesanetwork.org/aesa-working-paper-2-on-extension-research-in-india-current-status-and-future-strategies-p-sethurman-sivakumar-and-rasheed-sulaiman-v-december-2015/

I. Course Title : Capacity Development

II. Course Code : EXT 505

III. Credit Hours : 2+1

IV. Why this course?

Competent and skilful extension professionals are not naturally born. Their capacities need to be improved primarily at three different levels:

1. Pre-service capacity development – Under graduation and post-graduation studies
2. Induction capacity development – Just before job entry
3. In-service capacity development – During job

If undergone appropriately, pre-service studies help extension professionals to mainly acquire knowledge related to development. However, they are not fully ready for development work with required attitude and skills needed by an organisation. Properly planned and organized induction / in-service capacity building programmes help them to use development concepts, apply methods, exhibit attitude and skills required for development work at different levels. In short, the essence of this course is to make you understand these notions and help you to think up, manage, put into practice and evaluate capacity development programmes.

V. Aim of the course

- To understand the concepts of training, capacity building, capacity development and human resource development in the context of roles and responsibilities of extension professionals
- To discuss capacity development- approaches, strategies, needs assessment and methods / tolls
- To help you devise, organize, implement and evaluate capacity development programmes

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Capacity Development	1. Capacity Development - An Overview 2. Capacity Development - Approaches and Strategies 3. Planning and Organization of Capacity Development Programmes
2.	Capacity Development Needs Assessment	1. Capacity Development Needs Assessment - An Overview 2. Capacity Development Needs Assessment Methods
3.	Capacity Development Institutions and Management	1. Capacity Development Institutions 2. Capacity Development Project Formulation
4.	Capacity Development Process and HRD	1. Capacity Development Methods and Tools 2. Evaluation 3. Impact Assessment 4. Human Resource Development

VI. Theory

Block 1: Introduction to Capacity Development

Unit 1: Capacity Development–An Overview

Training, capacity building, capacity development and HRD-Meaning and differences; Need and principles of capacity development; Types and levels of capacities - Institutional capacities (include the rules, regulations and practices that set the overarching contextual environment), Organisational capacities (how various actors come together to perform given tasks), Individual capacities (technical, functional and leadership skills). Types of capacity building - Based on structure (structured, semi-structured &unstructured), Based on context (orientation, induction and refresher), and other categories (online, Webinar, distance etc.). Components of capacity development; Capacity development cycle.

Unit 2: Capacity Development- Approaches and Strategies

Capacity Development Dilemma- Theory versus Practice, Trainee versus Task, Structured versus Unstructured, Generic and Specific; Approaches in Capacity Development -Informative approach, Participatory approach, Experimental approach/ Experiential, Performance based approach; Capacity Development Strategies - Academic strategy, Laboratory strategy, Activity strategy, Action strategy, Personal development strategy, Organizational development strategy.

Unit 3: Planning and Organization of Capacity Development Programmes

Steps in Designing and Planning of Capacity Development- Step 1. Select the participants, Step 2. Determine the participants' needs, Step 3. Formulate goal and objectives, Step 4. Outline the content, Step 5. Develop instructional activities, Step 6. Prepare the design, Step 7. Prepare evaluation form, Step 8. Determine follow-up activities; Organising capacity development programme; Operational arrangements at different stages- Before the programme, During the programme, Middle of the programme, At the end of the programme, After the programme, Follow up; Stakeholders' responsibilities.

Block 2: Capacity Development Needs Assessment

Unit 1: Planning and Organization of Capacity Development Programmes

Concept of Need Assessment; Approaches in Need Analysis- Performance Analysis, Task Analysis, Competency Study; Needs Survey.

Unit 2: Capacity Development Needs Assessment Methods

Data Collection Methods in Identifying Needs - Rational Methods (Observation, Informal talks, Complaints, Comparison, Analysis of report, Opinion poll, Buzz session, Analysis of the new programme), Empirical Methods (Job analysis, Performance evaluation, Checklist or Questionnaire Method, Tests, Critical Incident Technique, Card Sort Method, Focus Group Discussion, Interview, SWOT Analysis); Information and Skills required in Need Analysis; Identification of Needs through Task Analysis - Task identification, Task Analysis, Gap Analysis.

Block 3: Capacity Development Institutions and Management

Unit 1: Capacity Development Institutions

Capacity Developer (Trainer): Meaning and concept; Types of Capacity Developers (regular, *ad-hoc*, part time, guest and consultants); Roles of Capacity Developer (explainer, clarifier, supporter, confronter, role model, linker, motivator, translator/ interpreter, change agent); Good Capacity Developer – Qualities, skills and roles Qualities, Skills (Intrapersonal & Inter personal), Roles (Manager, Strategist, Task Analyst, Media Specialist, Instructional Writer, Marketer, Facilitator, Instructor, Counsellor, Transfer Agent, Evaluator); Capacity Development Centres and Locations; Organisation's Role in Capacity Development.

Unit 2: Capacity Development Project Formulation

Project Proposal: Concept and Meaning; Steps in Project Formulation- Review of past proposals, Consulting experts, consultants, and previous organizers, Review past project evaluation reports, Interact with the prospective beneficiaries; Format for Writing Project Proposal (LFA).

Block 4: Capacity Development Process and HRD

Unit 1: Capacity Development Methods and Tools

Capacity Development Methods –Lecture, Discussion, Syndicate, Seminars, Conference, Symposium, Role Play, Case study, Programmed Instruction, T - group/ Laboratory methods; Factors Determining Selection of Methods - Capacity development objectives, subject matter, categories of participants, and the available resources like time, location, budget; Capacity Development Aids.

Unit 2: Evaluation

Capacity Development Programme Evaluation - Meaning & Importance; Purpose of Evaluation; Principles of Evaluation; Types of Evaluation – Formative, Summative, Kirkpatrick's four levels of evaluation; Process of Evaluation- Evaluation at the beginning, Evaluation during the programme, Evaluation at the end; Use of evaluation findings; Statistical Tools for evaluation.

Unit 3: Impact Assessment

Impact Assessment- Meaning, Need, Features, Benefits, Concepts; Indicators for Impact Assessment - Direct indicators, Indirect or proxy indicators, Quantitative indicators, Qualitative indicators, Result chain / hierarchy of indicators; Methods of Impact Evaluation- Learning retention of participants (KOSA), Impact on the job performance, Impact on organizational effectiveness, Impact on stakeholder's competency.

Unit 4: Human Resource Development

HRD: Meaning, Importance and Benefits; Types of HRD Systems & Sub-systems Career system (Manpower planning, Recruitment, Career planning, Succession planning, Retention), Work system (Role analysis, Role efficacy, Performance plan, Performance feedback and guidance, Performance appraisal, Promotion, Job rotation, Reward), Development system (Induction, Training, Job enrichment, Self-learning mechanisms, Potential appraisal, Succession development, Counselling, Mentor system), Self-renewal system (Survey, Action research, Organisational development interventions), Culture system (Vision, mission and goals, Values, Communication, Get together and celebrations, Task force, Small groups); Components of HRD System - Performance Appraisal, Potential Appraisal, Task System, Development System, Socialisation System, Governance; Functions of HRD-Organisational Development, Career Development, Capacity Development.

VII. Practicals

- Capacity development needs assessment exercise
- Capacity development project formulation exercise
- Planning organizing and conducting an extension capacity development programme
- Designing a programme
- Writing learning objectives
- Developing objectives into curriculum
- Training plan
- Organizing capacity development workshop
- Evaluation with pre- and post-training tests
- Training methods – Practicing each method mentioned in contents as group exercise

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group work
- Case Analysis
- Guest Lectures
- Review of training manuals and training evaluation studies
- Short attachments to a nearby training institute.

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Differentiate between training, capacity building, capacity development and human resource development
- Explain different levels of capacities, needs assessment approaches & methods, capacity development methods and tools
- Formulate, implement and evaluate need based capacity development programmes

X. Suggested Reading

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Bentaya GM, and Hoffmann V (Eds). 2011. *Rural Extension* Volume 3 -Training Concepts and Tools. Margraf Publishers GmbH, Scientific books, KanalstraBe 21; D-97990, Weikersheim, 191 pp.

DFID .2003. *Promoting Institutional and Organisational Development. A Source Book of Tools and Techniques,* Department for International Development, United Kingdom

DoPT.2014. *Civil Services Competency Dictionary: Strengthening Human Resource Management of Civil Service.* Department of Personnel and Training, Government of India

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FAO .2012. *Corporate Strategy on Capacity Development.*

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ICAR 2015. *Training Policy 2015*, Indian Council of Agricultural Research.

IISD 2015. *Appreciative Inquiry and Community Development.* International Institute for SustainableDevelopment.

LENCD 2011. *How to assess existing capacity and define capacity needs*, Learning Network onCapacity Development.

Maguire. 2012. *Module 2: Agricultural Education and Training to Support Agricultural Innovation Systems.Overview. Agricultural Innovation Systems: An Investment Source book.* The World Bank.

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UNDP. 2008. *Capacity Assessment Methodology. User's Guide*. Capacity Development Group. Bureaufor Development Policy.

UNDP. 2009. *Capacity Development: A UNDP Primer*, United Nations Development Programme

WAC. 2013. *Assessing Capacity Needs and Strategy Development for Grassroots Rural Institutions: A Guide for Facilitators.* World Agroforestry Centre (WAC)

Websites

TAP–Tropical Agriculture Platform for Capacity Development– https://www.tapipedia.org/

FAO–FAO Capacity Development– http://www.fao.org/capacity-development/en/

GFRAS–Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

AESA–Agricultural Extension in South Asia– http://www.aesanetwork.org/

I. Course Title : ICTs for Agricultural Extension and Advisory Services

II. Course Code : EXT 506

III. Credit Hours : 2+1

IV. Why this course?

Information and Communication Technologies (ICTs) are continuously evolving. More ICT applications having better relevance to extension and advisory services (EAS) are currently available considering the human and other resource constrains faced by EAS, ICTs can supplement and complement EAS extension efforts in a cost-effective way. Extension professionals should have sound knowledge of ICTs and comprehensive understanding on its various applications for effectively deploying these in EAS provision. This course will provide knowledge and hands-on-experience on ICT applications relevant for EAS.

V. Aim of the course

- To discuss different ICT initiatives, knowledge management process and application aspects

- To orient students on advances in smart/ disruptive technologies and data analytics
- Hands on experience in navigating ICTs

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Information and Communication Technologies (ICTS) and e-Extension	1. ICTs- Concepts and Status 2. ICTs in Knowledge Management 3. e-Extension initiatives in Agriculture and allied sectors
2.	Application of ICTs in Extension and advisory services	1. ICT Applications 2. ICT Expert Systems 3. ICT Networks
3.	Knowledge management and Standards	1. Policies in Knowledge Management 2. Web Standards 3. Social Media Applications to engage audience
4.	Smart and disruptive Technologies and advanced analytics for agricultural extension	1. Smart Technologies 2. Human Computer Interactions

VI. Theory

Block 1: Introduction to Information and Communication Technologies (ICTs) and E-extension

Unit 1: ICTs- Concepts and Status

ICTs- meaning, concepts, basics of ICTs, global and national status, types and functions of ICTs, innovations, meaning of e-Governance, e-learning, mLearning, advantages and limitations of ICTs.

Unit 2: ICTs in Knowledge Management

Knowledge management-meaning, approaches and tools. Role of ICTs in Agricultural Knowledge Management.

Unit 3: e-Extension initiatives in Agriculture and allied sectors

e-Extension, overview on Global and national e-extension initiatives, Inventory of e-Extension initiatives in Agriculture and allied sectors from Central and State governments, ICAR, SAUs, private sector and NGO initiatives in India.

Block 2: Application of ICTs in Extension and Advisory Services

Unit 1: ICT Applications

Knowledge centres (tele centres), digital kiosks, websites and web portals, community radio, farmers call centres, mobile phone based advisory services and mobile applications (mExtension, mLearning), Self-learning CDs on Package of practices, social media, digital videos, Market Intelligence and Information Systems- ICT enabled Supply-Chains and Value-Chains/ e-Marketing (e-NAM, Agmarknet, *etc.*).

Unit 2: ICT Expert Systems

Expert System/ Decision Support System/ Management Information Systems, Farm Health Management & Intelligence System for Plant Health, Animal Health, Soil Health, Fishery, Water, Weather, etc.

Unit 3: ICT Networks

Global and regional knowledge networks, international information management systems, e-Learning platforms (MOOCS, Course CCRA, EduEx, *etc*), e-Governance Systems; digital networks among extension personnel, Farmer Producers Organisations (FPOs)/ SHGs/ Farmers Groups.

Block 3: Knowledge Management and Standards

Unit 1: Policies in Knowledge Management

Global policy/ Standards on e-Governance, National policy on e-governance, Open Data / Open Gov Standards and Open Source etc; Language Technology Applications; National e-Agriculture policy/ Strategies/ guidelines.

Unit 2: Web Standards

Web standards, creating and writing for webportals, development of mobile applications, developing digital videos- story board- video recording- video editing, types of blogs and writing guidelines.

Unit 3: Social Media Applications to engage audience

Video conference, live streaming and webinars, types and functions of social media applications, guidelines for preparing social media content, engaging audience and data-analytics.

Block 4: Smart and Disruptive Technologies and Advanced Analytics for Agricultural Extension

Unit 1: Smart Technologies

Open technology computing facilities, System for data analytics/ mining/ modelling/ Development of Agricultural simulations; Remote Sensing, GIS, GPS, Information Utility (AIU); disruptive technologies- Analysis; Internet of Things (IoTs), Drones, Artificial intelligence (AI), block chain technology, social media and Big Data analytics for extension.

Unit 2: Human Computer Interactions

Human Centered Learning/Ergonomics/ Human Computer Interactions-Meaning; Theories of multimedia learning - Sweller's cognitive load theory, Mayer's cognitive theory of multimedia learning, Schnotz's integrative model of text and picture comprehension, van Merriënboer's four-component instructional design model for multimedia learning; Basic Principles of Multimedia Learning - Split-attention, Modality, Redundancy, Coherence, Signaling, segmenting, pre-training, personalisation, voice embodiment; Advanced principles - Guided discovery, worked examples, Self-explanation, drawing, feedback, multiple representation, Learner control, animation, collaboration, prior knowledge, and working memory. Designing ICT gadgets based on human interaction principles - Interactive design-Meaning, importance; Approaches of interactive design - user-centered design, activity-centered design, systems design, and genius design; Methods of interactive design - Usability testing methods.

VII. Practicals

- Content and client engagement analysis
- Designing extension content for ICTs
- Creating and designing web portals, blogs, social media pages
- Developing digital videos

- Live streaming extension programmes and organising webinars
- Working with Farmers call centres
- Engaging with professional digital networks
- Writing for digital media

VIII. Teaching methods/activities

- Lecture
- Guest Lectures
- Assignment (Reading/Writing/ developing mApps/ media management/Social media initiatives)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Student's interview of ICT practitioners/ champions
- Documenting good practices and case studies
- Review of ICT policy documents and guidelines/ standards
- Short internship with ICT projects

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the importance of the ICTs in EAS
- Understand the ICT application aspects
- Critically evaluate ICT initiatives and smart/disruptive technologies
- To execute extension functions by applying ICTs and
- Engage stakeholders in knowledge management process

X. Suggested Reading

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basic-knowledge-management-and-extension

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MEAS & Access Agriculture 2013. *A Guide to Producing Farmer-to-Farmer Training Videos*. https://www.agrilinks.org/sites/default/files/resource/files/MEAS%20Guide%20to%20Producing%20Farmer-to-Farmer%20Training%20 Videos%202013_04.pdf

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http://www.fao.org/research-and-extension/en/

CTA–The Technical Centre for Agricultural and Rural Cooperation: Digitalization–
https://www.cta.int/en/channel/digitalisation-sid05951b8c7-e611-4f34-9ae6-8c0fc0c822bc

GFRAS–Global Forum for Rural Advisory Services–
http://www.g-fras.org/en/

AESA–Agricultural Extension in South Asia–
http://www.aesanetwork.org/

I. Course Title : Evaluation and Impact Assessment

II. Course Code : EXT 507

III. Credit Hours : 2+1

IV. Why this course?

Many organizations now look for experts to evaluate development projects and developmental interventions. It is now required that impact be assessed whenever any development programme is implemented. Thus, the extension professionals need to have good understanding of the theory and practice of programme evaluation and impact assessment. This course, thus, has been designed to help students develop as extension professionals who can plan and conduct systematic assessments of the results and impacts of extension programmes.

V. Aim of the course

- To orient students on the importance of evaluation and impact assessment
- To develop capacities for evaluation and impact assessment
- Discuss ways of conducting evaluations and impact assessment

The course is organized as follows:

No	Blocks	Units
1.	Programme Evaluation	1. Introduction to Evaluation 2. Evaluation Theories
2.	Evaluation Process	1. How to Conduct Evaluation 2. Evaluating the Evaluation

No	Blocks	Units
3.	Programme Management Techniques	1. SWOT Analysis and Bar Charts 2. Networks
4.	Programme Evaluation Tools	1. Bennett's Hierarchy of Evaluation 2. Logic Framework Approach
5.	Impact Assessment	1. Introduction to Impact Assessment 2. Impact Assessment Indicators 3. Approaches to Impact Assessment 4. Environment Impact Assessment

VI. Theory

Block 1: Programme Evaluation

Unit 1: Introduction to Evaluation

Concept of Evaluation: Meaning and concept in different contexts; Why Evaluation is Done and When? Programme planning, analyse programme effectiveness, decision making, accountability, impact assessment, policy advocacy; Objectives, types, criteria and approaches of programme evaluation, evaluation principles; the context of program evaluation in agricultural extension; Role and Credibility of Evaluator: Role as educator, facilitator, consultant, interpreter, mediator and change agent. Competency and credibility of evaluator.

Unit 2: Evaluation Theories

Evaluation theory vs. practice – synergistic role between practice and theory in evaluation; Evaluation theories - Three broad categories of theories that evaluators use in their works - programme theory, social science theory, and evaluation theory (other theories/ approaches - Utilization-Focused Evaluation & Utilization-Focused Evaluation (U-FE) Checklist, Values Engaged Evaluation, Empowerment Evaluation, Theory-Driven Evaluation). Integration between theory and practice of evaluation: –evaluation forums, workshops, conferences and apprenticeship/ internship.

Block 2: Evaluation Process

Unit 1: How to Conduct Evaluation

Ten Steps in programme evaluation: (1) Identify and describe programme you want to evaluate (2) Identify the phase of the programme(design, start-up, on-going, wrap-up, follow-up) and type of evaluation study needed (needs assessment, baseline, formative, summative, follow-up) (3) Assess the feasibility of implementing an evaluation (4) Identify and consult key stakeholders (5) Identify approaches to data collection (quantitative, qualitative, mixed) (6) Select data collection techniques (survey interviews and questionnaires with different types) (7) Identify population and select sample (sampling for evaluation, sample size, errors, sampling techniques (8) Collect, analyse and interpret data (qualitative and quantitative evaluation data analysis) (9) Communicate findings (reporting plan, evaluation report types, reporting results, reporting tips, reporting negative findings (10) Apply and use findings (programme continuation/ discontinuation, improve on-going programme, plan future programmes and inform programme stakeholders).

Unit 2: Evaluating the Evaluation

Evaluating the Evaluation - 10 Steps as above with focus on conceptual clarity, representation of programme components and stakeholders, sensitivity, representativeness of needs, sample and data, technical adequacy, methods used for data collection and analysis, costs, recommendations and reports.

Block 3: Programme Management Techniques

Unit 1: SWOT Analysis and Bar Charts

SWOT Analysis – Concept, origin and evolution; SWOT As a Programme Management Tool; Conducting SWOT Analysis - Common Questions in SWOT Analysis; Advantages and Disadvantages of SWOT; Bar Charts (Gantt Charts and Milestone Charts) - Characteristics, advantages and limitations.

Unit 2: Networks

Networks – Introduction, origin and widely used networks (Programme Evaluation and Review Technique (PERT) and Critical Path Method (CPM), differences between PERT and CPM, advantages and disadvantages. Networks Terminology – Activity, Dummy activity, Event (predecessor event, successor event, burst event, merge event, critical event), Earliest Start Time (EST), Latest Start Time (LST), Critical Path, Critical Activity, Optimistic time (T_o), Pessimistic time (P_o), Most likely time (T_M), Expected time (T_E), Float or Slack, Event Slack, Lead time, Lag time, Fast tracking, Crashing critical path, Acclivity Table, Danglers, Normal Time. Rules for Preparation of Networks and Steps in Network Preparation with example.

Block 4: Programme Evaluation Tools

Unit 1: Bennett's Hierarchy of Evaluation

Introduction to Bennett's hierarchy – Background and description; Relation between programme objectives & outcomes at 7 levels of Bennett's hierarchy – Inputs, activities, participation, reactions, KASA changes, practice and behaviour changes, end results. Advantages and Disadvantages of Bennett's hierarchy

Unit 2: Logic Framework Approach (LFA)

Introduction to LFA – Background and description; Variations of LFA - Goal Oriented Project Planning (GOPP) or Objectives Oriented Project Planning (OOPP); LFA Four-by-Four Grid – Rows from bottom to top (Activities, Outputs, Purpose and Goal & Columns representing types of information about the events (Narrative description, Objectively Verifiable Indicators (OVIs) of these events taking place, Means of Verification (MoV) where information will be available on the OVIs, and Assumptions). Advantages and Disadvantages of LFA.

Block 5: Impact Assessment

Unit 1: Introduction to Impact Assessment

Concept of Impact Assessment: Meaning, concept and purpose in different contexts; Impact Assessment Framework: Meaning of inputs, outputs, outcomes, impacts and their relation with monitoring, evaluation and impact assessment.

Unit 2: Impact Assessment Indicators

Indicators for impact assessment – meaning and concept; Selecting impact indicators; Types of impact indicators for technology and extension advisory services - social and behavioral indicators, socio-cultural indicators, technology level indicators, environmental impact assessment indicators and institutional impact assessment indicators.

Unit 3: Approaches for Impact Assessment

Impact assessment approaches – Quantitative, qualitative, participatory and mixed methods with their advantages and disadvantages; Quantitative Impact Assessment Types – Based on Time of Assessment (Ex-ante and ex-post), Based on Research Design (Experimental, quasi experimental, Non-experimental). Econometric Impact Assessment: - (Partial Budgeting Technique, Net Present Value, Benefit Cost Ratio, Internal Rate of Return, Adoption Quotient, *etc*). Qualitative and Participatory Impact Assessment Methods.

Unit 4: Environment Impact Assessment (EIA)

Concept of EIA – Introduction, What it is? Who does it? Why it is conducted? How it is done?; Benefits and important aspects of EIA-risk assessment, environmental management and post product monitoring. Environmental Components of EIA – air, noise, water, biological, land; Composition of the expert committees and Steps in EIA process - screening, scoping, collection of baseline data, impact prediction, mitigation measures and EIA report, public hearing, decision making, monitoring and implementation of environmental management plan, assessment of alternatives, delineation of mitigation measures and EIA report; Salient Features of 2006 Amendment to EIA Notification - Environmental Clearance/Rejection, participants of EIA; Shortcomings of EIA and How to improve EIA process?

VII. Practicals

- Search the literature using web / printed resources and identify evaluation indicators for the following:
  - Utilization-Focused Evaluation
  - Values Engaged Evaluation
  - Empowerment Evaluation
  - Theory-Driven Evaluation
- Visit Directorate of Extension in your university and enquire about extension programmes being implemented / coordinated by Directorate. Develop an evaluation proposal of any one programme using 'Ten Steps in Programme Evaluation' discussed in the theory class.
- Review any comprehensive programme evaluation report from published sources. Evaluate the report and write your observations following the 'Evaluating the Evaluation' approach.
- Identify at least four agriculture development programmes and their objectives being implemented in your state. Write two attributes each on Strengths, Weaknesses, Opportunities and Threats related to the identified programme objectives in the SWOT grid.
- Identify an on-going development programme and make-out 6 activities from the programme.
- Draw a Gantt chart for 12 months programme activities.
- Write a report on evaluation hierarchy levels and indicators as per Bennett's hierarchy of evaluation for any development programme or project.
- Develop LFA four-by-four grid for any development programme or project with activities, outputs, purpose and goal and objectively verifiable indicators, means of verification & assumptions.
- Visit a nearby KVKs / ATIC. Select any agriculture technology with package of practices and extension advisory services promoted by KVK / ATIC. Identify impact assessment indicators for social and behavioral indicators, socio-cultural indicators,

technology level indicators, environmental impact assessment indicators and institutional impact assessment indicators.

- Refer any Environment Impact Assessment report and analyse steps in EIA. Write your observations.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to: Develop competencies in the areas of evaluation planning, indicator development, conducting evaluation and impact assessment and writing reports.

X. Suggested Reading

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TAP– Tropical Agriculture Platform: Monitoring and Evaluation - www.tapipedia.org

GFRAS– Global Forum for Rural Advisory Services http://www.g-fras.org/en/

AESA– Agricultural Extension in South Asia http://www.aesanetwork.org/
USAID– United States Agency for International Development: Evaluation https://www.usaid.gov/evaluation
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I. Course Title : Managing Extension Organizations

II. Course Code : EXT 508

III. Credit Hours : 2+1

IV. Why this course?

Organizations need to follow management principles, objectives and organizational processes. The extension organizations including management of agricultural extension services need to be managed for effectiveness and efficiency. This calls for key business management skills to be learnt by the students so that they can run extension organizations, and extension and advisory services efficiently using the principles, practices, knowledge and skills required for effective management.

V. Aim of the course

- To orient students on the importance of knowledge and skills on various management functions, as applicable to extension organizations
- Discuss ways of running extension services as managers of agri-ventures
- To develop capacities for becoming effective managers of agri-ventures

The course is organized as follows:

No	Blocks	Units
1.	Basics of Management	1. Management- An Over view
2.	Management in different types of Extension organizations	1. Extension Management in public, private sector and other sectors 2. Concepts in Management
3	Motivation and Organizational Communication	1. Motivation and Communication 2. Supervision and Control

VI. Theory

Block 1: Basics of Management

Unit 1: Management- An Over view

Management and Extension management – Meaning, concept, nature and importance;
and theories of management. Management, administration and supervision - meaning, definition and scope; Approaches to management, Principles, functions and levels of management; Qualities and skills of a manager; Interpersonal relations in the organization; Reporting and budgeting

Block 2: Management in different types of Extension Organizations

Unit 1: Extension Management in public, private sector and other sectors

Extension management (POSDCORB) in public sector, Department of Agriculture, Agricultural Technology Management Agency (ATMA), Krishi Vigyan Kendra (KVK), SAUs, ICAR Institutes, Private sector, Cooperatives, NGOs, FPOs etc. Organisational Structure, Relations between different units- Challenges in management

Unit 2: Concepts in Management

Decision making – Concept, Types of decisions, Styles and techniques of decision making, Steps in DM Process, Guidelines for making effective decisions; Human Resource Management: Manpower planning, Recruitment, Selection, Placement and Orientation, Training and Development; Dealing with fund and staff shortages in different extension organizations (KVK, ATMA etc.); Leadership – Concept, Characteristics, Functions, Approaches to leadership, Leadership styles; Authority and responsibility, Delegation and decentralization, line and staff relations; Challenges of co-ordination in extension organizations; Managing interdepartmental coordination and convergence between KVK, ATMA and line departments; Coordinating pluralism in extension services; Challenges in managing public-private partnerships (PPPs) at different levels in agricultural development in general and extension in particular; Performance appraisal – Meaning, Concept, Methods.

Block 3: Motivation and Organizational Communication

Unit 1: Motivation and Communication

Managing work motivation – Concept, Motivation and Performance, Approaches to motivation, team building; Organizational Communication – Concept, Process, Types, Networks, Barriers to Communication; Mentoring, Time management, Team work and team-building strategies; Modernization of information handling

Unit 2: Supervision and Control

Supervision – Meaning, Responsibilities, Qualities and functions of supervision, Essentials of effective supervision; Managerial Control – Nature, Process, Types, Techniques of Control, Observation, PERT and CPM, Management Information Systems (MIS): Concept, tools and techniques, MIS in extension organizations.

VII. Practicals

- Simulated exercises on techniques of decision making
- Study the structure and function of agro-enterprises, Designing organizational structure/ organograms.
- Group activity on leadership development skills
- Simulated exercise to understand management processes
- Field visit to extension organizations (ATARI, KVKs, NGOs), FPOs, dairy cooperatives to understand the functions of management
- Practical exercises on PERT & CPM
- Group exercise on development of short term and long term plans for agro-enterprises
- Developing model agriculture-based projects including feasibility study, financial planning and cost-benefit analysis

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student’s Book/Publication Review
– Student presentation
– Group Work
– Student’s interview of officers engaged in EAS
– Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Turn good managers of extension and advisory services including agri-ventures, FPOs, cooperatives etc.
- understand the key business skills needed for managing agribusinesses and managing the value chains
- critically evaluate the Management functions to make extension systems efficient by applying management principles and good practices of effective management
- engage in management of extension organizations

X. Suggested Reading

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I. Course Title : Enabling Innovation
II. Course code : EXT 509
III. Credit Hours : 1+1

IV. Why this course?

An effective process of agricultural innovation is a pre-condition for meeting the global challenge of feeding the growing world population and reducing poverty. Ideas about innovation have evolved considerably over the past 4 decades. A frequently used term in the discussions around innovation in agriculture is 'Agricultural Innovation Systems' (AIS). The AIS is increasingly recognized as a useful framework to diagnose innovation capacity, design investment and organise scaling up interventions. Extension and Advisory Services (EAS) are integral to AIS. Extension professionals should have sound knowledge on how to scale up new knowledge and thereby enabling innovation and impact and their roles in strengthening AIS. This course aims to provide these perspectives.

V. Aim of the course

The aim of this course is to introduce the new perspectives related to "innovation" and help learners to apply the AIS framework especially in dealing with scaling up knowledge. It discusses the different ways to explore AIS including the roles of different actors and the enabling environment (including institutions and policies) in enabling innovation. The course also aims to broaden the understanding of students in scaling up knowledge and orient students to varied tools and approaches to scaling up

The course is organized as follows:

No	Blocks	Units
1	Agricultural Innovation Systems	1. Agricultural Innovation Systems: Concepts and Elements 2. Enabling Innovation
2	Scaling Up Knowledge for Innovation	1. Scaling Up: Tools, Approaches and Pathways

VI. Theory

Block 1: Agricultural Innovation Systems

Unit 1: Agricultural Innovation Systems: Concepts and Elements

Origins of the innovation systems concept-Innovation vs Invention; Agricultural Innovation System (AIS) -ToT, FSR, AKIS and AIS compared, Key insights from AIS: How Innovation takes place; Role of different actors in AIS; Importance of interaction and knowledge flows among different actors, Role of Communication in Innovation Process; Role of Extension in AIS, Different views to analyze AIS: structural view, functional view, process view and capacity view.

Unit 2: Enabling Innovation

Role of enabling environment: Policies and institutions in enabling innovation; Role of Government-Innovation Policy: Achieving coordination and policy coherence;

Innovation Platforms; Role of Innovation Brokers, Methodologies for AIS Diagnosis: Typologies of existing methodologies-strengths and limitations; Assessing Extension and Advisory Services within AIS; Capacity Development in AIS: Strengthening capacities to innovate.

Block 2: Scaling Up Knowledge for Innovation

Unit 1: Scaling Up: Tools, Approaches and Pathways

Scaling Up: Definitions; Changing views on scaling up: Approaches to Scaling Up: Push, pull, plant, probe: Scaling up pathways: Drivers and spaces for scaling up; Framework and Tools for Scaling up: Planning and implementing a scaling up pathways; Scalability assessment tools; Role of policies in scaling up: Influencing policies for scaling up; Innovation Management for scaling up knowledge and implications for Extension and Advisory Services.

VII. Practical

- Identify one crop/commodity sector and use AIS framework to diagnose actors and their roles, patterns of interaction, institutions determining interaction and the enabling policy environment and develop a AIS Diagnosis Report (Review and Key informant interviews)
- Undertake a case study on a successful case of scaling up knowledge and identify factors that contributed to its success
- Identify one specific knowledge (a technology, an approach) that has been recently introduced and develop an Up scaling Strategy

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Appreciate and apply AIS framework in different contexts
- Enhance their knowledge and skills related to enabling innovation
- Diagnose AIS and design interventions for improvement and
- Design scaling up strategies to achieve innovation and impact

X. Suggested Reading

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FAO- Food and Agricultural Organisation (Research and Extension)– http://www.fao.org/research-and-extension/en/

GFRAS- Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

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I. Course Title : Gender Mainstreaming

II. Course Code : EXT 510

III. Credit Hours : 2+1

IV. Why this course?

Gender as a concept has gained well deserved attention globally. Development planners and policy makers have realized that gender implications need to be considered while planning and implementing programmes and projects for their desired impacts. Conversely, the impacts of programmes on men and women also vary due to their different socially ascribed roles and responsibilities. Extension professionals need to understand the concept of gender and its implications on agricultural and rural development and their skills need to be built for critically identifying and analysing gender implications. This course is designed to meet these requirements.

V. Aim of the course

- To orient students on the importance of "Gender mainstreaming" as well as the other concepts related to gender. The students will be able to understand the gender roles and responsibilities and how in the present times, the roles may be shifting
- To discuss ways and various techniques for conducting gender analysis theoretically and practically as well as the prerequisites for gender analysis
- To develop capacities for identifying and addressing gender implications in all development programmes related to agriculture and allied sectors, climate change adaptation and livelihood security, as well as addressing gender issues through application of extension methods including PRA and PLA

The course is organized as follows:

No	Blocks	Units
1.	Why Gender Matters	1. Historical Perspective of Gender 2. Agrarian Importance of Gender
2.	Gender Related Concepts, Analysis, Gender and Technology	1. Gender Related Concepts and Divides 2. Gender Analysis 3. Gender and Technology
3.	Gender Mainstreaming and Women Empowerment	1. Gender Mainstreaming 2. Women Empowerment 3. Global Best Practices, Policies and Frameworks 4. Entrepreneurship Development for Women

VI. Theory

Block 1: Why Gender Matters?

Unit 1: Historical Perspective of Gender

Historical perspective of gender: Feminism and emergence of gender as a concept, Scope of gender studies in agriculture and rural development

Unit 2: Agrarian Importance of Gender

Agrarian Importance of Gender: Understanding the importance of gender in national and global agriculture-Key gender issues and challenges in agriculture - Gender and value chain- Global actions to address gender-needs and strategies to address gender and women empowerment.

Block 2: Gender Related Concepts, Analysis, Gender and Technology

Unit 1: Gender Related Concepts and Divides

Gender related concepts and divides: Understanding of the concepts of gender, gender equality and equity, gender balance, gender blindness, gender relations, gender neutrality, gender bias and discrimination, gender rights, gender roles and responsibilities. Gender budgeting, Gender divides and their implications such as gender digital divide, gender access to resources and inputs divide, gender mobility divide, gender wage divide, Gender needs: practical and strategic.

Unit 2: Gender Analysis

Gender analysis: Importance, usage, prerequisites, techniques of gender analysis-Tools for gender analysis.

Unit 3: Gender and Technology

Gender and technology: How gender and technology impact each other, Gender neutral technology, Gender sensitive technology, Gender supportive assistance in technology adoption-Gender in agricultural research and extension.

Block 3: Gender Mainstreaming and Women Empowerment

Unit 1: Gender Mainstreaming

Gender mainstreaming: Importance of gender mainstreaming in agriculture, Extension strategies to address gender issues such as gender and health, nutrition, gender in agricultural value chains, gender and climate change adaptation, gender and globalization& liberalization for mainstreaming gender concerns into the national programmes and policies.

Unit 2: Women Empowerment

Women Empowerment: Importance of women empowerment, Current national women empowerment and gender indices. Women empowerment approaches (technological, organizational, political, financial, social, legal and psychological), Case studies based on experiences and learning from various development and rural development programmes.

Unit 3: Global Best Practices, Policies and Frameworks

Global Best Practices, Policies and Frameworks: Global best practices, women empowerment and gender mainstreaming models and frameworks for addressing gender concerns in agriculture, approaches of various organizations: gender mainstreaming and special women focused programmes in agriculture and rural development.

Unit 4: Entrepreneurship Development for Women

Entrepreneurship development for women: Women entrepreneurship development in agriculture and agro processing: current status, women led enterprises, supporting organizations and schemes, Govt. policies, entrepreneurship development programme and process for women in agriculture.

VII. Practicals

- Visit to a village for understanding rural gender roles and responsibilities as groups, followed by class presentation by groups
- Exercise for capturing shifts in gender roles and responsibilities
- Conducting gender analysis in a village using gender analysis techniques
- Visit to agencies supporting women empowerment followed by report presentation. Each student to visit a different organization such as State Rural Livelihood Mission, Women Development Corporation, Department of Agriculture, Important NGOs working for women empowerment
- Exercise for identification and prioritization of issues affecting/needs for women empowerment
- Interaction with a successful women entrepreneur/ SHG

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Student's interview of key policy makers
- Case Analysis
- Guest Lectures
- Review of policy documents
- Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the importance of addressing agrarian gender concerns in the context of sustainable livelihoods and national development
- Understand the various concepts related to gender and the application of these concepts for women empowerment and gender mainstreaming
- Critically evaluate the various agricultural development, rural development programmes, schemes, policies and strategies for women empowerment within the context of achieving gender equity
- How to engage in gender analysis and collect and analyse sex-disaggregated data for developing strategies for women empowerment and gender mainstreaming

X. Suggested Reading

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Liz P. 2018. *Implementing Gender Transformative Approaches (GTAs) in Agricultural Initiatives.* IGENAES and USAID. https://ingenaes.illinois.edu/wp-content/uploads/ING-DP-2018_06-Gender-Transformative-Approaches-in-Agricultural-Initiatives-Poulsen.pdf

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GFRAS- Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

INGENAES- Integrating Gender and Nutrition within Agricultural Extension Services– https://www.agrilinks.org/activities/ingenaes-integrating-gender-and-nutrition-within-agricultural-extension-services

RRW- Reaching Rural Women– http://www.reachingruralwomen.org/

UN WOMEN– http://www.unwomen.org/en

Course Title with Credit Load
Ph.D. in Agricultural Extension Education

Major Courses 12

Course Code	Title of Course	Credit Hours
EXT-601*	Policy Engagement and Extension	2+1
EXT-602*	Methodologies for Social and Behavioural Sciences	2+1
EXT-603*	Technology Commercialization and Incubation	2+1
EXT-604*	Educational Technology and Instructional Design	2+1

Minor Courses 06

a. It is suggested the student may choose at least one out of three courses listed below as part of minor courses as these are related to policy advocacy and bring in global perspectives with an aim to build a larger understanding of the subject to the student.
b. Further, it is suggested that the student may choose the remaining Courses from any other discipline including the disciplines of Agrl. Economics/ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/HOD.

EXT-605	Risk Management and Climate Change Adaptation	2+1
EXT-606	Livelihood Development	1+1
EXT-607	Facilitation for People centric Development	2+1

Supporting Courses 05

STAT	Multivariate Statistical Methods for Extension Research	2+1
COM	Multimedia and Applications	1+1

It is suggested that the student may choose the Supporting Courses other than the listed courses, provided the opted courses are related to the research problem selected by the student and be mandatorily approved by the Student Advisory committee/HOD".

Seminars 2

EXT-691	Doctoral Seminar-I	1+0
EXT-692	Doctoral Seminar-II	1+0
	ii. Thesis / Research	75
	Total	100

Course Contents
Ph.D. in Agricultural Extension Education

I. Course Title : Policy Engagement and Extension

II. Course Code : EXT 601

III. Credit Hours : 2+1

IV. Why this course?

Extension's performance in any country to a large extent is dependent on the wider policy and institutional context prevailing at the national level. At the organizational level, extension should have capacities to influence policies that affect their performance. To effectively influence policies, extension professionals need to generate not only sound evidence of its impact, but also capacities to engage with policy relevant actors especially at various levels. While few countries have developed specific extension policies, there has been very limited success in translating these policies into programmes and operational guidelines. Lack of policy relevant research to generate evidence on extension's impact; poor documentation of successful initiatives, and lack of training on engaging with policy relevant actors have all contributed to this. Extension professionals, often encounter situations where existing policy constraints development interventions or where new policies could better support development. This course is aimed at developing these capacities to successfully engage with policy actors and bringing about desirable policy changes to strengthen extension.

V. Aim of the course

- To orient students on the importance of policies in shaping extension's performance
- To discuss ways of generating policy relevant evidence to influence policies
- To develop capacities to engage with policy actors and the policy development process

The course is organized as follows:

No	Blocks	Units
1.	Why policies matter?	1. Understanding Policy 2. Policy Advocacy and Tools 3. Policy Analysis 4. Policy Development Process
2.	Using evidence to influence Policy Change	1. Influencing Policy Change 2. Global Experience with Extension Policy

VI. Theory

Block 1: Why Policies Matter?

Unit 1: Understanding Policy

Why policies are important for extension? Role in providing structure, ensure funding and framework for providing functions-examples; Policy: definitions and types: Is policy a product or a process or both? Policies and institutions-How these influence defining organisational roles and performance in extension organizations-Role of policies in upscaling knowledge-Role of extension in influencing policies to enable innovation.

Unit 2: Policy Advocacy and Tools

Definition of advocacy, Approaches to policy advocacy-Advising, Media campaigning, Lobbying, Activism, Information Education Communication (IEC) and Behavior Change Communication (BCC); Advocacy for Rural Advisory Services (RAS); Policy advocacy strategy

Unit 3: Policy Analysis

Explain the meaning and use of policy analysis in decision- making; Describe different types of policy analysis- empirical, evaluative or normative policy analysis, retrospective/ prospective policy analysis, predictive/prescriptive/descriptive policy analysis; How to do policy analysis? - understand the process of policy analysis, highlight the different methods and techniques used in policy analysis, doing ethical policy analysis; Tools for policy impact- research tools, context assessment tools, communication tools, policy influence tools

Unit 4: Policy Development Process

Policy development process: Who drives policy change?: National Governments, Donors, Civil Society-varied experiences: Understanding the environment and key actors in policy space- problem identification-policy adoption, implementation and evaluation; stakeholder mapping, identifying opportunities and barriers, mobilising financial resources; Dealing with policy incoherence: identifying contradictions and challenges in policy implementation

Block 2: Using Evidence to Influence Policy Change

Unit 1: Influencing Policy Change

Generating evidence: Role of policy research; analyzing the usefulness and appropriateness of the evidence; Using evidence in policy advocacy; Understanding your audience: analyzing channels of influence; creating alliances; identifying policy champions; Defining goals and objectives; Developing advocacy messages: Policy papers, Policy briefs, good practice notes, *etc.*: Good practices in influencing policies Organising policy dialogues: Policy engagement strategy-Engaging with policy makers: GO and NGO experiences; Policy working groups; advisory panels; use of committees: Use of media including ICTs and social media for influencing policies.

Unit 2: Global Experience with Extension Policy

Extension policy in different countries: Explicit extension policy Vs extension as part of Agriculture Policy, Challenges in policy implementation: lack of capacities, financial resources, ownership, lack of stakeholder consultations: Strengthening capacities in extension to influence policies: Global Forum for Rural Advisory Services (GFRAS)'s efforts in strengthening extension policy advocacy: policy compendium, training modules, training for strengthening capacities to influence policies.

VII. Practicals

- Analysis of country/state level agricultural/extension policy to understand the policy intentions from strengthening EAS

- Analysis of extension policy of other countries: policy intentions, processes adopted in development of the policy and mechanisms of policy implementation
- Interview key policy actors in EAS arena at the state/national level (eg: Director of Agriculture, Director of Extension in SAU, Chairman/Managing Director of Commodity Board. Member Agriculture, State Planning Board) to explore policy level challenges in EAS
- Identify what evidence policy makers look for from extension research? Is the evidence available? If so what form? (Reports, Briefs etc), If not, develop a plan
- Explore how different stakeholders influence policies (eg: policy advocacy of prominent NGOs, private sector and public sector) -What mechanisms and tools they use
- Identify policy level bottlenecks that constrain effective EAS delivery at the district level- Eg: Issues around linkages between KVK and ATMA; inter-departmental collaboration; public private partnerships; joint action etc.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Student's interview of key policy makers
– Case Analysis
– Guest Lectures
– Review of policy documents
– Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Appreciate the role of policies in shaping performance of extension
– Understand how to generate and communicate policy relevant evidence
– Critically evaluate extension policies in different countries
– How to engage in policy advocacy.

X. Suggested Reading

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I. Course Title : Methodologies for Social and Behavioural Research

II. Course Code : EXT 602

III. Credit Hours : 2+1

IV. Why this course?

In general, social and behavioural science research plays a crucial role in the professional development in a subject domain, through advancing knowledge and developing working modalities and standards. Precisely, the empirical research helps to develop robust and outcome focused working strategies, processes and models to enable the professionals to maximise their efficiency. This course on advanced social science research caters to the need to equipping the scholars with essential skills in conducting high quality research which helps them to design working strategies, processes and models for professional development.

V. Aim of the course

This course aims to equip the doctoral students to conduct outcome-oriented social and behavioural science research and to develop sound field focused extension strategies and models with adequate replicability, while advancing knowledge on processes governing success of those strategies. The focus of the course is on equipping the scholars with advanced capacities in conducting systematic, objective and outcome oriented research by applying state-of-art methods and tools at every stage of research from planning to publishing.

The course is organized as follows:

No	Blocks	Units
1.	Advanced methods for improving quality of research data	1. Measurement Properties of Research Instruments 2. Threats to Data Quality
2.	Scales, indexes and tests	1. Scales, Indexes and Tests-1 2. Scales, Indexes and Tests-2

No	Blocks	Units
3.	Emerging research approaches and designs	1. Qualitative Research Methods 2. Emerging Approaches
4.	Utilising research outputs	1. Publishing Research 2. Ethics in Extension Research

VI. Theory

Block 1: Advanced Methods for Improving Quality of Research Data

Unit 1: Measurement Properties of Research Instruments

Measurement properties – Dimensionality, reliability and validity; Dimensionality – Unidimensionality and multidimensionality, Methods of assessing dimensionality, Formative and reflective constructs; Validity - Importance, Internal validity - face validity; content validity, Substantive Validity, Structural Validity; External validity - Convergent and Discriminant Validity, known-group validity, Criterion-Related Validity, Consequential Validity, nomological validity; Methods of assessing various forms of validities – Judges rating, Lawshe's Content Validity Ratio, Item-objective congruence index; latent variable method; Reliability - Internal consistency reliability – Split-Half, Cronbach alpha; Temporal Stability reliability - test-retest method; Interrater Consistency and Consensus – inter rater reliability and interrater agreement; Alternative Forms or parallel forms reliability – Reliability of difference - Factors Affecting the Validity and Reliability of Test Scores; Generalizability Theory

Unit 2: Threats to Data Quality

Errors and biases; Errors – Meaning and sources; Types - Sampling error, Non-sampling or measurement error and Processing error – Meaning, causes; Effects of errors and biases on data quality; Bias in behavioural research – Meaning, causes, Types – Respondent and researcher biases; Methods of reducing errors and biases in surveys, questionnaires, personal interviews, focus groups and online methods

Block 2: Scales, Indexes and Tests

Unit 1: Scales, Indexes and Tests-1

Approaches to measurement and scale development - Classical test theory. Formative or index models, The C–OAR–SE approach and Item Response Theory; Item analysis in Classical test theory – item difficulty and item discrimination; Scoring performance in scales and tests – meaning, types and methods; Scale development strategies – deductive and empirical; Stimulus-centred scales – method of equally appearing intervals, paired comparison, Person scaling – Q methodology; Subject-centre scales – The Likert scale and Semantic Differential

Unit 2: Scales, Indexes and Tests-2

Steps in constructing a multi-dimensional scale using confirmatory factor analysis,; Response scales - Guttman's scalogram analysis and The Rasch method; Indexes –Meaning, types, importance; Similarities and differences with scales, Methods of constructing indexes; Common indexes used in extension. Measurement invariance –Meaning, types, methods of assessing measurement invariance. Tests – meaning, types, importance; steps in conducting various tests – knowledge test

Block 3: Emerging Research Approaches and Designs

Unit 1: Qualitative Research Methods

Qualitative methods – Meaning; Types – Ethnography, Grounded theory, Phenomenology, Ecological psychology, Discourse Analysis; Observational research; Case study research – Sampling and sample size; Data collection methods - In-depth interviews, Focus groups, Direct observation, Record review; Content analysis; Unobtrusive Measures; Projective and semi-projective techniques; Selecting right qualitative method – Strengths and limitations of qualitative research; Analysis and interpretation of qualitative research data; Research synthesis – meaning, importance, methods; Systematic reviews and meta analysis – meaning, steps, and applications; Policy research

Unit 2: Emerging Approaches

Mixed methods research – meaning, purpose, types and applications; Participatory research – Meaning, importance, types, methods and tools and applications; Action research – Meaning, importance, Principles, Types, Steps in conducting action research, application in behavioural sciences. Social Network Analysis – Meaning, importance, types, steps in social network analysis, applications; Advanced methods of measuring perception and beliefs. Multi criteria decision making, analytical hierarchy approach

Block 4: Utilising Research Outputs

Unit 1: Publishing Research

Scholarly communication process; Research reports – Meaning, types, contents; Presentations – Meaning, types, principles of good presentation - Tell 'Em" and KISS 'Em" principles; Research publications – meaning, importance, types; Guidelines for preparing research papers - Peer review process, citation styles; Open access publishing; Publishing in social media. Software in academic writing

Unit 2: Ethics in Extension Research

Ethics in conducting behavioural research; Human subject research – Meaning, history, and ethical guidelines; Ethical aspects of collecting and using Indigenous knowledge and farmers technologies; Ethical practices in publishing; Plagiarism – meaning, sources, Identifying and correcting plagiarism in a research paper using anti-plagiarism software

VII. Practicals

- Practice in developing research instruments
- Methods of assessing measurement properties of research instruments - dimensionality, reliability and validity
- Hands-on exercise in minimising errors and biases
- Hands-on experience in constructing tests, scale and indexes
- Practice in summated scale development using confirmatory factor analysis
- Hands on experience in assessing measurement invariance
- Practicing and collecting data using participatory tools and techniques, analyzing and interpreting qualitative data
- Hands-on experience in writing systematic review using meta-analysis
- Field practice in conducting action research
- Practical experience in writing research paper
- Hands on exercises using software for qualitative data analysis
- Practice in detecting and correcting plagiarism using software

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work
- Guest Lectures
- Research Report (Writing)

IX. Learning outcome

- The scholars should develop critical skills in conducting systematic and objective research by using robust methods while minimising biases and errors
- The students should intelligently choose and apply advanced methods and tools at every stage of research and execute them in a objective way by managing the actors and processes effectively
- The students should develop expertise in designing tests, scales and indexes along with other tools to measure the socio-psychological processes at individual, group and community levels

X. Suggested Reading

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I. Course Title : Technology Commercialisation And Incubation

II. Course Code : EXT 603

III. Credit Hours : 2+1

IV. Why this course?

The technology commercialisation and incubation is an emerging area which links technology development, transfer and commercialisation processes with entrepreneurship development. Technology commercialisation aims to realize the value of agricultural technologies developed at the research establishments, by maximising their utility to stakeholders. With the increasing awareness of protecting and commercialising the Intellectual Property Resources (IPR) in the free market economy, there is a need to understand the organic relationship between protection and commercialisation IPR, and entrepreneurship development.

V. Aim of the course

This course is aimed to develop a critical understanding among extension students about how the technology commercialisation process is linked to IPR management and entrepreneurship development.

The course is organized as follows:

No	Blocks	Units
1.	Technology commercialisation and the modern context	1. Basics of Technology Commercialisation 2. Nature of Agricultural Technology 3. Basics of Technology Transfer and Commercialisation
2.	Intellectual Property Resources (IPR) Management	1. Overview of Intellectual Property Resources 2. Systems for protecting IP 3. Management of IPR 4. Protection and Management of Biological Resources 5. Protection, Management and Commercialisation of Grass root and Farmers Innovations, Traditional and Indigenous Knowledge 6. Geographical Indications (GI) and Appellation of Origin 7. Genetically Modified Organisms (GMO), Agriculture and Biosafety
3.	Technology commercialisation	1. Technology Assessment and Refinement 2. Technology Valuation 3. Technology Commercialisation Strategies 4. Scaling up of Technologies 5. Technology Licensing 6. Technology Takers and Entrepreneurship 7. Policy Support for Technology Commercialisation and Entrepreneurship Development
4.	Technology Incubation	1. Basics of Technology Incubation 2. Technology Incubation in India
5.	Technology promotion and essential skills for technology commercialisation	1. Technology Promotion 2. Dealing with Entrepreneurs, Agripreneurs and Other Stakeholders
6.	Emerging approaches in technology commercialisation and incubation	1. Technology Scouting

VI. Theory

Block 1: Technology Commercialisation and the Modern Context

Unit 1: Basics of technology commercialisation

Technology - Definition, functions, process of technological advancement – invention, discovery, innovation and technology; types of innovation - Basic research, Breakthrough innovation, Disruptive Innovation and Sustaining Innovation; Technology transfer and commercialisation

Unit 2: Nature of Agricultural Technology

Agricultural technology – meaning, types; technology generation system; technology life cycle

Unit 3: Basics of Technology transfer and commercialisation

Technology transfer Vs Commercialisation; Technology commercialisation process – elements, models, systems and processes; Technology transfer model – research, disclosure, development and commercialisation

Block 2: Intellectual Property Resources (Ipr) Management

Unit 1: Overview of Intellectual Property Resources

Introduction to IPR; Overview & Importance; Genesis; IPR in India and IPR abroad; Patents, copyrights, trademarks & trade secrets, geographical indication, industrial design; Emergence of IPR Regimes and Governance Frameworks - Trade-Related Aspects of Intellectual Property Rights (TRIPS), Convention on Biological Diversity (CBD), Cartagena Protocol, International Union for Protection of New Plant Varieties (UPOV), and BIMSTEC.

Unit 2: Systems for Protecting IP

IPR protection laws and systems – National IPR Policy; and IPR laws; procedures for filing IP protection; Systems of IP protection and management in agricultural universities and research institutions and also by stakeholders

Unit 3: Management of IPR

Mechanisms of IPR Management – Institutional arrangement, IP Management processes – invention disclosure; IP portfolio management; Infringement management

Unit 4: Protection and Management of Biological Resources

Introduction; National Biodiversity Act (2002); Protection of Plant Varieties and Farmers Rights Act (2001); Guidelines for registration and transfer of biological resources; Farmers rights; Mechanisms of documenting/ collecting, protecting and commercialising farmers varieties and other biological resources; National Biodiversity Authority, PPVFRA and other agencies involved in management of biological resources in India. Access to Genetic Resources and Sharing of Benefits

Unit 5: Protection, Management and Commercialisation of Grassrootand Farmers Innovations, Traditional and Indigenous Knowledge

Traditional and Indigenous Knowledge, Grassroot and Farmers Innovations – Meaning, forms and importance; Systems of documentation, registration, protection and commercialisation. Documentation of traditional indigenous knowledge - Traditional Knowledge Digital Library (TKDL), Community Biodiversity Registers

(CBRs), People's Biodiversity Registers (PBRs), Plant Biodiversity Register, and Honeybee Network.

Unit 6: Geographical Indications (GI) and Appellation of Origin

Geographical indications and appellation of origin – meaning, origin; Geographical Indications of Goods (Registration and Protection) Act (1999); Documentation, registration and commercialisation of GI protected materials and processes.

Unit 7: Genetically Modified Organisms (GMO), Agriculture and Biosafety

The Global Concerns on Use of Genetically Modified Organisms in Food and Agriculture; The Cartagena Protocol on Bio-safety; Regulation of GMO in India - Recombinant DNA Advisory Committee (RDAC), Institutional Bio-safety Committee (IBSC), Review Committee on Genetic Manipulation (RCGM), Genetic Engineering Approval Committee (GEAC), State Bio-safety Coordination Committee (SBCC) and District Level Committee (DLC). Laws and Acts for regulation of GMO - Guidelines for Research in Transgenic Plants, 1998; Seed Policy, 2002; Plant Quarantine Order, 2003; Regulation for Import of GM Products Under Foreign Trade Policy, 2006; National Environment Policy, 2006

Block 3: Technology Commercialisation

Unit 1: Technology Assessment and Refinement

Meaning; Importance; Approaches and methods of assessment and refinement of various technologies – stakeholder oriented approaches including participatory technology assessment and refinement; assessment and refinement of traditional and indigenous knowledge and grassroot innovations

Unit 2: Technology Valuation

Returns to investment; IP Valuation-Oxford context, IP Valuation methods - Cost approach; Income approach - Discounted Cash Flow, Risk-Adjusted Net Present Value, Net Present Value with Monte Carlo Simulation and Real Options Theory; Market approach - Industry Standards Method, Rating/Ranking Method, Rules of Thumb Approach and Auction Method; Hybrid approaches; Royalty rate method

Unit 3: Technology Commercialisation Strategies

Meaning- approaches for technology commercialisation – technology scaling up, technology licensing, handholding, agripreneur development, technology business incubation

Unit 4: Scaling up of Technologies

Meaning, types and stages of technology scaling up; mechanisms

Unit 5: Technology Licensing

Meaning and types - Procedures of licensing, preparing licensing documents; Management of technology licensing process

Unit 6: Technology Takers and Entrepreneurship

Meaning; types of technology takers; Technology Taking as a Strategy; Types of entrepreneurship – agripreneurs, startups, small businesses, Producer Organizations, Self Help Groups, Clusters and other forms of entrepreneurship

Unit 7: Policy support for Technology Commercialisation and Entrepreneurship Development

Policy support for entrepreneurship development in India - National Policy on Skill

Development and Entrepreneurship and other polices; Government of India Support for Innovation and Entrepreneurship – Startup India, Make in India, Digital India, Atal Innovation Mission and others; Entrepreneurship policy and schemes at different states of India; Organisations promoting entrepreneurship in India

Block 4: Technology Incubation

Unit 1: Basics of Technology Incubation

Meaning, functions and types; stakeholder oriented incubation process – Livelihood incubation, village incubators

Unit 2: Technology Incubation in India

System of technology incubation- incubation process; its effectiveness; Managing profit oriented and non-profit incubators; Schemes for promoting incubators in India

Block 5: Technology Promotion And Essential Skills For Technology Commercialisation

Unit 1: Technology Promotion

Technology promotion – meaning, types, business meetings, scientist-industry/ entrepreneur meets, technology conclave, business plan competition, farmers fairs, technology shows

Unit 2: Dealing with Entrepreneurs, Agripreneurs and Other Stakeholders

Business communication; Business Etiquette; business networking

Block 6: Emerging Approaches in Technology Commercialisation and Incubation

Unit 1: Technology Scouting

Technology Scouting and Innovations in technology incubation

VII. Practicals

- Understanding the technology commercialisation process – Visit to Technology Commercialisation Unit of ICAR Institute/ Agricultural University
- Understanding the IPR protection practices – Visit to Patent Attorney office
- Hands-on experience in drafting IPR application – Patent/Copyright/ Trademark
- Understanding protection of biological resources including plant varieties – Visit to PPVFRA Branch office/ ICAR Institute or Agricultural University involved in plant variety protection
- Documenting Traditional and indigenous knowledge – Field experience in using various protocols of using traditional and indigenous knowledge
- Protecting unique local goods through Geographical Indications – Hands on experiences in documenting and registering Geographical indications
- Technology assessment/ validation of traditional and indigenous knowledge – QuIK and other methods
- Hands on experience in technology valuation
- Hands on experience in technology licensing process including drafting agreements
- Understanding the Technology Business Incubation – Visit to Agri Business Incubator or Technology Business incubator
- Hands on experience in planning and organising technology promotion events

- Hands on experience in various techniques in business communication and Business etiquette

VIII. Teaching methods/activities

- Lecture cum discussion
- Cases
- Class exercises
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Group Presentation

IX. Learning outcome

At the end of the course the students are expected to develop competencies in:

- Enabling stakeholders to protect and manage their IPR
- Managing IPR to maximise their value realisation through commercialisation, and
- Providing mentoring and handholding support to agripreneurs, rural entrepreneurs, start-ups, Farmer Organisations and other forms of entrepreneurs through incubation

X. Suggested Reading

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I. Course Title : Educational Technology and Instructional Design

II. Course Code : EXT 604

III. Credit Hours : 2+1

IV. Why this course?

Technology, digital media and mobile access have drastically changed how people learn. And the field of education is rapidly becoming a dynamic opportunity for interactive instruction. Today's curriculum developers and instruction designers, especially in the extension and RAS ecosystem, need to equip themselves with the continuous developments in both theory and practice of instructional design so as to create satisfying learning experiences. Similarly, knowledge and skilful use of social media and disruptive technologies like internet of things (IOT), augmented reality, artificial intelligence, etc. makes this course essential for extension professionals who are expected to act as harbingers of change.

V. Aim of the course

The aim is to develop knowledgeable, responsive and effective teachers committed to educating diverse group of learners in a dynamic extension landscape. This course will help the learners to appreciate the role of technology in learning and how it can be integrated into instructional design to create engaging learning experience in both classroom and online learning environment. The course also aims to prepare the students as competent professionals employable in the extension and RAS providers both as specialised researchers as well as designers.

The course is organized as follows:

No	Blocks	Units
1.	Educational Technology	1. The Landscape of Educational Technology and Instructional Design 2. Theories of learning 3. Technology Enabled Learning
2	Instructional Design	1. Theories of Instruction 2. Creating Instruction 3. Instructional Strategies 4. Evaluating Instruction 5. Trends in Instructional Design

VI. Theory

Block 1: Educational Technology

Unit 1: The Landscape of Educational Technology and Instructional Design

Understanding various terms - educational technology, instructional design, instructional systems design, curriculum design, pedagogy, andragogy; Brief overview of the origin and evolution of ET and ID as theory and practice; what is the relevance of ET and ID relevant in extension and rural advisory services? Extensional professionals as instructional designers and architects of the learning experience

Unit 2: Theories of Learning

What is learning? Critical overview of Behaviorism, Cognitivism, Constructivism and Complex learning theories; instructional designers and learning theories; Types of learning or learning domains- Bloom's taxonomy of the cognitive domain, Krathwohl and Bloom's affective domain and Simpson's psychomotor domain

Unit 3: Technology Enabled Learning

What is the role of technology in education? Digital media, new tools and technology; Open and distance Learning (ODL); Online Education - Synchronous and Asynchronous learning models; eLearning, Massive Open Online Courses - SWAYAM, Open Education Resources (OERs), Course CERA, EduEx, CoL, RLOs; digital education and its applications in higher agricultural education; Smart classrooms and Campuses, Web-based remote laboratory (WBRL); Integrating media and digital tools into ID; types and implications of disruptive technologies for higher education and extension; Augmented learning; Adaptive learning; meaning, features and good practices in using open source Learning Management Systems (Moodle); Quality assurance and certification in e-learning.

Block 2: Instructional Design

Unit 1: Theories and Models of Instruction

Howard Gardner's Theory of Multiple Intelligences, David Kolb's Experiential Learning Cycle, Albert Bandura's Social Learning Theory, Rand Spiro's Cognitive Flexibility Theory and Its Application In eLearning, Wlodkowski's Motivational Framework for Culturally Responsive Adult Learning; ADDIE Model, Dick and Carey Model, SAM Model, Bloom's Taxonomy; integrating the theories of instruction into the practice of ID in extension and RAS ecosystem.

Unit 2: Creating Instruction

Overview of planning, designing and implementing the curricula and learning experiences; Needs Analysis - meaning, approaches and steps; Task and content analysis - meaning, approaches, steps and techniques (topic analysis, procedural analysis, and the critical incident method); Learner analysis – meaning, importance and approaches, relevance of Maslow's Hierarchy of Needs and learning styles, Captive Audience vs. Willing Volunteers, Universal vs. user-centered design, Learner Analysis Procedures; Writing learning objectives: Meaning of Learning Goal and Learning Objectives; ABCDs of well-stated objectives; Setting goals, translating goals into objectives; Contextualising ADDIE process within the Extension learning environment

Unit 3: Instructional Strategies

Organizing content and learning activities - scope and sequence of instruction; Posner's levels of organizing (Macro, Micro, Vertical, and Horizontal) and structures of organizing (content vs. media) instruction, Gagne's events of instruction, Edgar Dale's Cone of Experience; Methods of Delivery- classroom teaching, programmed instruction, synchronous and asynchronous modes of distance education; Changing role of a teacher in classroom and teaching competencies

Unit 4: Evaluating Instruction

Meaning of Assessment, Measurement and Evaluation; Developing learner evaluations and their reliability & validity; assessment techniques for measuring change in knowledge, skill and attitude of learners - Objective Test Items, Constructed-Response Tests, Direct Testing, Performance Ratings, Observations and Anecdotal Records, Rubrics, Portfolios, Surveys and Questionnaires, Self-Reporting Inventories, Interviews; Conducting learner evaluation pre-, during and post-instruction; Formative and Summative Evaluation- meaning, approaches and steps; Evaluating Learner Achievement and the Instructional Design Process; Evaluating the success of instruction; Performance appraisal of teachers

Unit 5: Trends in Instructional Design

Alternatives to ADDIE model - Rapid prototyping and constructivist ID, reflections on instructional design as science and as an art; Relating ID models and process in extension learning environment; political economy of higher education in developed and developing countries; University assessment and rating methods, returns from agricultural higher education; research in education and instructional design.

VII. Practicals

- Exercises on preparation of the Analysis Report that includes the task/content analysis and learner analysis and the Design Plan includes learning objectives and corresponding instructional strategies and assessment items

- Prepare course outline and lesson plan with an appreciation for diverse learning styles based on temperament, gender, and cultural/ethnic differences and deliver a lecture for UG/PG students
- Assessing learning styles through Barsch and Kolb inventories
- Development and testing of survey instruments for evaluating learning outcomes/ competencies of students
- Development and testing of survey instruments for performance appraisal / competency assessment of teachers.
- Design an online e-learning module on a topic of interest as a capstone project - integrate and apply the knowledge and skills gained from the course for creating an effective learning experience for a target audience
- Designing and developing a theme based knowledge portals
- Exercises on designing an online course using open source LMS like moodle or EdX
- Select and evaluate or design for social al media
- Prepare a short research paper on recent theories and models of instructional design
- Interview an instructional designer of your choice and prepare a synthesis report about what job roles he/she perform, What ID processes does he or she use, challenges faced
- Develop a prototype for one of the lessons in your design plan using PowerPoint or a website builder such as Weebly to create the screens integrating multimedia content and various functionalities
- Field visit to a virtual learning / augmented learning labs, e-learning labs, distance learning centres, etc.
- Hands-on practice with video-editing software, web conferencing and video conferencing solutions

VIII. Teaching methods/activities

- Lectures & Videos
- Individual and group assignments
- Group discussion and debating
- Enactive learning exercises
- Case studies / Case analysis
- Storyboarding
- Guest Lectures
- Field Visits
- Capstone Project
- Prototype development

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Develop a critical understanding of concepts of learning and education within the context of agricultural development
- Relate and apply learning theories and models to the development, design and evaluation of courses utilizing educational technology and instructional design
- Hone their skills to take up research work in analysing and evaluating different

learning systems, teaching-learning environments, competencies and learning outcomes

– Find placement opportunities in the industry for job profiles such as e-learning specialist, training officer, curriculum developer, instructional designer, education consultant, etc.

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International Society for Educational Technology– https://www.isfet.org/courses/
Educational Technology– https://educationaltechnology.net/
AESA-Agricultural Extension in South Asia– http://www.aesanetwork.org/
GFRAS-Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

I. Course Title : Risk Management and Climate Change Adaptation

II. Course Code : EXT 605

III. Credit Hours : 2+1

IV. Why this course?

Present agriculture and allied sectors India face tremendous challenges on multiple fronts. Agrarian distress and the climate change impacts together pose grave dangers to food, nutritional and ecological security. As change agents, extensional professionals in particular and agricultural graduates in general need to quip themselves with knowledge and skill sets required to navigate the climate change scenario so as to help reduce risk and vulnerability. Hence, this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of risks management and climate change adaptation with reference to Indian agriculture. This course will approach the subjects from a multidisciplinary

perspective - technical, socio-economic, political, financial, and regulatory. It aims to equip students to identify, evaluate and evolve ways to address (mitigate and manage) risks and climate change.
The course is organized as follows:

No	Blocks	Units
1	Risk Management in Agriculture	1. Understanding Risk and Distress 2. Managing Risk and Distress in Agriculture 3. Extension Professionals and Risk management
2	Adapting to Climate Change	1. Introduction to Climate Change Science 2. Introduction to Climate Change Adaptation and Mitigation 3. Climate Smart Agriculture and Extension Advisory Services

VI. Thory

Block 1: Risk Management in Agriculture

Unit 1: Understanding Risk and Distress

Introduction to risk, risk management, uncertainty, sensitivity and distress, General risk theory, Risk analysis methods, Risk perception and decision making, Indicators of risk and distress in agriculture – identification, selection and assessment, Understanding the agrarian distress in Indian agriculture, Sources of distress in Indian farming -changing farm size, land use, cropping patterns, pricing policy, markets and terms of trade, Typology of crisis in agriculture; Droughts, floods and Indian agriculture, Distress and farmer suicides - causes and socio-economic consequences

Unit 2: Managing Risk and Distress

Ways to reducing/managing risk and distress in Indian agriculture; crop and life insurance; Developing support systems; Planning, implementation and evaluation of risk/distress management programs; Institutional frameworks for risk and disaster management - NDMA & SDMAs; Developing District Agriculture Contingency Plans; Risk management by diversification; Good practices and lessons from other countries; Responses of government, non-government and extension system to agrarian crisis; National Farmers Policy.

Unit 3: Extension Professionals and Risk management

Understanding social-psychological and behavioural dimensions of farmers under risk/distress; Risk perception and communication; Helping farmers manage farm level risks - mobilising resources, linking with markets, strengthening capacities; Working with village level risk management committees; Operational skills for preparing contingency and disaster management plans; Institutional and extension innovations in managing risk and distress; Policy and technological preferences for dealing with drought and flood.

Block 2: Adapting to Climate Change

Unit 1: Introduction to Climate Change Science

Basic concepts of and terms in climate change science; impacts of climate change;

anthropogenic drivers of climate change, Climate change and Indian agriculture; climate adaptation vs. disaster risk reduction; anticipated costs of adaptation; climate change and poor; Overview of UNFCCC framework and institutions, Kyoto Protocol and beyond; India's National Action Plan on Climate Change and National Mission on Strategic Knowledge on Climate Change; National Coastal Mission, Institutional arrangements for managing climate change agenda.

Unit 2: Introduction to Climate Change Adaptation and Mitigation

Introduction to Climate Change Adaptation, Conducting a vulnerability assessment (CVI and SEVI frameworks), Identifying and selecting adaptation options; Global, national and state level initiatives and plans to support climate change adaptation, private sector and civil society initiatives and activities; Mainstreaming climate change adaptation into development planning, Financing climate adaptation and budgetary allocations for programmes, Gender and climate change adaptation, Agricultural development programmes and strategies towards climate change adaptation and mitigation, Community based and Ecosystem based adaptation strategies, preparing evidence based intervention plans for vulnerability reduction at micro and macro-levels.

Unit3: Climate Smart Agriculture (CSA) and Extension &Advisory Services

Climate smart agriculture; Developing climate smart and climate resilient villages; Stakeholders and determinants involved in climate smart agriculture; Climate smart agriculture and EAS; Innovative extension approaches used in CSA; Climate information services, Farmers perceptions about climate change; Farm and household level manifestations and adaptation strategies; Barriers and limits to adaptation; Farmers feedback on performance of extension methods; Skills, competencies and tools required for extension professionals at different levels and development departments in up scaling CSA.

VII. Practicals

- Hands-on practice in using risk assessment/analysis tools
- Case studies on risk / distress assessment in agriculture -Indian and global
- Lessons / Experiences from NICRA Project in agriculture and allied sectors
- Developing criteria, indicators and indices for assessment of risk, vulnerability and resilience
- Hands on practice on use of vulnerability and risk assessment tools and techniques
- Case studies on success stories of climate change adaptation and community based initiatives
- Developing district and village level intervention plans for climate change adaptation
- Field Visits to State Disaster Management Authority
- Case studies on climate smart agriculture / villages from India and world
- Case studies on impact assessment of crop insurance programs, disaster management programs
- Capstone project on documenting ITKs and local practices related to reducing risk / climate resilience agriculture

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review

– Student presentation
– Group Work
– Student's interview of key policy makers
– Case Analysis and case studies Guest Lectures
– Review of policy documents

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Appreciate the scientific foundation of risk management and climate change science and relate the key learning to the job of an extension professional
– Utilise methods and tools for risk and climate related vulnerability assessments and adaptation strategies in the context of Indian agriculture / farming scenario
– Utilise material in scientific publications relevant for risk management and climate change adaptation and critically reflect on their benefits and limitations for decision making

X. Suggested Reading

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Websites

CSA-Centre for Sustainable Agriculture– http://csa-india.org/

GFRAS-Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

AESA-Agricultural Extension in South Asia– http://www.aesanetwork.org/

NICRA-National Innovations in Climate Resilient Agriculture–
http://www.nicra-icar.in/nicrarevised/

CRIDA-Central Research Institute for Dryland Agriculture– http://www.crida.in/

UNCC: Learn- UN Climate Change Learning Partnership– https://www.uncclearn.org/

DST- Department of Science and Technology- Climate Change Programme, GoI–
http://www.dst.gov.in/climate-change-programme

I. Course Title : Livelihood Development

II. Course Code : EXT 606

III. Credit Hours : 1+1

IV. Why this course?

One of the aims of extension work is to enhance and expand the sustainable livelihood opportunities for individuals in a society. For this a thorough understanding of the different aspects of livelihood and its interface with nature becomes imperative. Resource poor farmers and the socially and politically weaker sections of the society currently face several challenges in expanding their livelihoods. Keeping these in view, the course has been designed to provide a theoretical framework for understanding of the basic concepts, definitions and approaches related to 'livelihood', 'vulnerability' 'institutional processes', and 'development and policies' pertaining to livelihood development in India.

V. Aim of the course

- To develop an understanding on the concept of livelihood and its various forms
- To acquaint the students regarding the various alternative approaches that has been adopted to support livelihoods
- To familiarize the students to some of the methods, tools and techniques they can utilize to design livelihood interventions
- To expose the students to the context, especially the economic models and policy environment that guides the livelihood choices
- To equip students to work in multidisciplinary teams and engage at multiple levels on livelihood issues

The course is organized as follows:

No	Blocks	Units
1.	Understanding of Livelihood	1. Concept of Livelihoods 2. Livelihood Challenges
2.	Livelihood Analysis	1. Livelihood Frameworks 2. Designing Livelihood Intervention and Promotion
3.	Livelihood Augmentation	1. Pathways for LA

VI. Theory

Block 1: Understanding of Livelihood

Unit 1: Concept of Livelihoods

Basic concepts of livelihood and Development, Types of development-Immanent/ inherent and interventionist/ intentional; Why promote livelihood; Livelihood intervention: definition, types-Spatial, segmental, sector –sub-sector; Systemic view of Livelihoods, Understanding Rural Livelihoods-Farm, Non-Farm, and off farm; Linkages with Farm and Off-farm Livelihoods; Economic Models

Unit 2: Livelihood Challenges

Livelihood Challenge- Political economy of Livelihoods, Issues of access to farm and non-farm livelihoods; Livelihoods from a Gender Perspective-Feminization of agriculture/ poverty, women in the unorganized sector, the issue of unpaid and informal work; Livelihood Coping Mechanism- Climate Change and Livelihoods; Livelihoods and Disasters

Block 2: Livelihood Analysis

Unit 1: Livelihood Frameworks

Sustainable Livelihoods Approaches (SLAs)-Definition and origins of SLA; Assets or capitals and capabilities in SLA and its linkage to the other capitals: Physical, Social, Economic, Human, Natural; Vulnerability Assessment- Shocks, trends, seasonality; Policies, institutional context and processes; Conceptual Frameworks-DFID, CARE, UNDP, OXFAM, BASIX livelihood triad, Nine square Mandala or Rural Livelihood System's Framework, etc.; Past, Present and possibilities for the future of the SLA, critiques of the approach

Unit 2: Designing Livelihood Intervention and Promotion

Designing a suitable livelihood intervention-Observing and Understanding the Local Economy; Selecting livelihood activities suitable for the poor in the area; Deciding on the interventions. Livelihood promotion approaches-Poverty and livelihood: Approaches and programs in India; Livelihood and a Rights Based Approach-MGNREGA and its critique; Livelihood and a Social Capital based approach: NRLM

Block 3: Livelihood Augmentation (LA)

Unit 1: Pathways for LA

Basic concepts; Pathways: a) Entrepreneurial strategies for LA; b) NRM based intervention; c) Market based interventions including Value-chain analysis; d) ICT based interventions; e) Livelihood and allied agriculture (dairy, poultry, Goatery, etc.) based livelihood; f) Forest based Livelihoods vis a vis Livelihood Protection and Promotion: Contribution of NTFP in supporting rural livelihoods
Note: Block 'A' and 'B' is theoretical; Block 'C' should be covered in the form practical's supported by few classroom discussion through cases

VII. Practicals

- Village stays to understand the livelihood pattern of villagers and how the other socio-economic factors affect the livelihood of people
- Visit to institutes/ universities adopted and/or nearby villages to experience the life and natural resources in rural communities-understanding of village culture, evolution, social structure, livelihood pattern, trends, governance arrangements, and the natural context (landscape layout, land use, vegetation types etc)
- Application of participatory rural appraisal skills for understanding village context; Engagement of working with rural communities and their grass-root institutions, understanding dynamics of working in a group
- Visit to different agri-business models as mentioned in the Block 'C'. Group assignments may be given to document the field experience in the form of case study of an enterprise/ entrepreneur/ members and other related stakeholders

VIII. Teaching methods/activities

- Interactive Lectures – by sharing in advance a reading material
- Analysis of case studies
- Audio-visual of successful/ failure models of agribusiness firms
- Guest session by field practitioners, if possible

– Group presentations by the students
– Field visit and field based individual or group assignments

IX. Learning outcome

This course will equip students with perspectives, knowledge and skills to develop a comprehensive understanding of the livelihood concepts, various forms, approaches, tools and techniques to analyze existing livelihood pattern and strategies the sustainable livelihood intervention in the rural areas.

X. Suggested Reading

Anonymous. 2010. *State of India's Livelihood Report.* Edited by Sankar Datta and Vipin Sharma. Sage Publications, New Delhi.

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Desai RM and Joshi S. 2014. *Can Producer Associations Improve Rural Livelihoods? Evidence from Farmer Centres in India,* The Journal of Development Studies, 50 (1): 64-80.

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Morse S and McNamara N. 2009. *Sustainable Livelihood Approach: A critique of theory and practice,* Springer Science. (Chapter 2)

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Scoones Ian. 1998. *Sustainable Rural Livelihoods: A Framework for Analysis*, IDS Working Paper 72.

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I. Course Title : Facilitation for People Centric Development

II. Course Code : EXT 607

III. Credit Hours : 2+1

IV. Why this course?

The prime aim of the agricultural extension professionals is to influence development change among the stakeholders with whom they work. In the Agricultural Innovation Systems (AIS) context, this change will happen when good relationships, networks and partnerships are formed. A new extension approach that aims at participatory and group learning as well as networking, where the extensionist acts as a facilitator is needed. It is important to inculcate the good facilitation skills by the extension professional to increase the effectiveness and impact among the agricultural extension and advisory services stakeholders.

V. Aim of the course

- To orient students on the importance facilitation
- To inspires students to understand facilitation tools to influence change at the individual, group and organisational levels
- To develop capacities in multi-stakeholder engagement, facilitation and networking

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Facilitation for Development	1. Facilitation for Development in the AIS 2. Principles, Attributes and Skills for Facilitation for Development
2.	Facilitating change in individuals, groups and organizations	1. Realise Potential- Self-Discovery 2. Group Dynamics and Working Together 3. Organizational Change Process
3.	Facilitating operational level multi-stakeholder engagements	1. Multi-Stakeholder Interactions 2. Innovation and Policy Engagement Platforms
4.	Brokering strategic partnerships, networking and facilitation	1. Linkages, Partnerships, Alliances and Networking 2. Facilitating Capacity Development

VI. Theory

Block 1: Introduction to Facilitation for Development

Unit 1: Facilitation for development in the AIS

Facilitation for development in the AIS; Understanding facilitation for development; Importance of facilitation as a core function of extension within the Agricultural Innovation Systems (AIS)

Unit 2: Principles, Attributes and Skills for Facilitation for Development

Basic principles of facilitation for development; Desired attributes of facilitator for development- Cognitive attributes, Emotional attributes (Emotional intelligence), Social, behavioural and attitudinal attributes; Technical skills of a facilitator for development- Design processes, Facilitation techniques and tools, the art of questioning and probing, Process observation and documentation, Visualisation

Block 2: Facilitating Change in Individuals, Groups and Organisations

Unit 1: Realise Potential- Self-Discovery

Self-discovery to realise our potentials, Tools for self-discovery, formulating a personal vision, Taking responsibility for your own development

Unit 2: Group Dynamics and Working Together

Understanding the dynamics of human interaction, Group dynamics and power relations, Managing relationships, Shared vision and collective action, Tools for team building

Unit 3: Organizational Change Process

Organizational change process, Organizational learning to adapt to changing environments, Enhancing performance of organizations, Leadership development, Tools for organizational change

Block 3: Facilitating Operational Level Multi-stakeholder Engagements

Unit 1: Multi-Stakeholder Interactions

Defining stakeholders, Development of collective and shared goals, Building trust and accountability, Tools for stakeholder identification and visioning

Unit 2: Innovation and Policy engagement Platforms

Visualising innovation platforms (IPs), Why are IPs important?, Different models of IPs for multi-stakeholder engagement, policy engagement platforms, Generating issues and evidence for policy action, Advocacy for responsive policy processes

Block 4: Brokering Strategic Partnerships, Networking And Facilitation

Unit 1: Linkages, Partnerships, Alliances and Networking

Brokering linkages and strategic partnerships, Identification of critical links, Knowledge brokering, Creating linkages with markets, Learning alliances and networking, Coordination of pluralistic service provision within the AIS, The concept of action learning and reflective practitioners, Networking

Unit 2: Facilitating Capacity Development

Facilitating Capacity Development-Facilitate participation and learning in development programs and projects. Virtual platforms- skills for strengthening dialogue, collaboration, shared commitment amongst diverse actors and stakeholders

VII. Practicals

- Practicing facilitation techniques,
- Self discovery exercises,
- Working together and interaction (task based),
- Arrangement for multi-stakeholder interactions,
- Understanding organisational change process tools and techniques,
- Case analysis on organisational change process,
- Participating with innovation platforms,
- Policy engagement platforms,
- Stakeholder analysis mapping,
- Exercise on networking skills,
- Facilitating capacity building programmes
- Facilitating virtual platforms
- Filed visit to multi-stakeholder partnership projects

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Facilitation Manual/Publication Review
– Student presentation
– Group Work
– Student's interview with facilitators
– Case Analysis
– Guest Lectures
– Review of facilitation methodologies
– Short internships

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Appreciate the importance of facilitation skills and tools
– Understand facilitation and networking techniques
– Critically evaluate strategic partnerships and linkages
– How to manage group dynamics and engage multi-stakeholders and virtual platforms

X. Suggested Reading

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Koutsouris A. 2012. *Exploring the emerging facilitation and brokerage roles for agricultural extension education*. AUA Working Paper Series No. 2012-4. Agricultural University of Athens. Department of Agricultural Economics & Rural Development.
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http://documents.worldbank.org/curated/en/564521467995077219/pdf/103509-BRI-PUBLIC-ADD-series-ILAC-brief.pdf

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Mittal N, Sulaiman RV and Prasad RM. 2016. *Assessing Capacity Needs of Extension and Advisory Services A Guide for Facilitators*. Agricultural Extension in South Asia.
http://www.aesanetwork.org/assessing-capacity-needs-of-extension-and-advisory-services-a-guide-for-facilitators/

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Villet, V V. 2015. *Motivation Theory by David McClelland.* https://www.mindtools.com/pages/article/human-motivation-theory.htm

Websites

- **MSU**–Michigan State University Extension Facilitation– https://www.canr.msu.edu/facilitation/
- **TAPipedia**– Tropical Agriculture Platform– https://www.tapipedia.org/
- **CGSpace**- A Repository of Agricultural Research Outputs by CGIAR– https://cgspace.cgiar.org/handle/10568/33667
- **UMaine**– The University of Maine– https://extension.umaine.edu/community/strengthening-your-facilitation-skills/
- **GFRAS**– Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

I. Course Title : Multivariate Statistical Methods For Extension Research

II. Course Code : STAT

III. Credit Hours : 2+1

IV. Why this course?

With increasing complexity in agricultural systems, research problems in extension are becoming multi-dimensional and often influenced by the composite of biological, social and economical factors. Such complex problems require advanced analytical methods and tools derived from statistical and other decision sciences.

V. Aim of the course

This course aims to equip the students with critical skills in choosing appropriate analytical tools and interpreting the results for solving complex and multidimensional extension research problems.

The course is organized as follows:

No	Blocks	Units
1.	Overview of Multivariate Statistical Methods	1. Basics of Multivariate Statistical Methods (MVSM) 2. Classification and Types of MVSM 3. Selecting Appropriate MVSM 4. A structured Approach for Building Multivariate Statistical Models 5. Basic Econometric Methods-1 6. Basic Econometric Methods-2
2.	Data preparation and cleaning	1. Missing Data Analysis and Outlier Management 2. Testing Assumptions of MVSM and Data Transformation
3.	Methods for assessing human choice/ preferences and decision-making	1. Assessing Human Preference Structures Using Conjoint Analysis 2. Assessment of Adoption of Agricultural Technologies Using Limited Dependent Variable Models 3. Multidimensional Scaling 4. Multi-criteria Decision-making
4.	Methods of assessing association and causality	1. Multiple Correlation and Multiple Regression 2. Discriminant Analysis
5	Methods of grouping objects/ variables based on latent variables	1. Principal Component Analysis (PCA) and Common Factor Analysis 2. Structural Equation Modeling (SEM)–Two units 3. Cluster Analysis
6	Emerging MV statistical methods	1. Emerging MV Statistical Methods

VI. Learning outcome

At the end of this course, the students will be able – To choose appropriate multivariate statistical methods based on research problem/ situation – To design, implement and interpret in a skilful way using SPSS

VII. Theory

Block 1: Overview of Multivariate Statistical Methods

Unit 1: Basics of Multivariate Statistical Methods (MVSM)

What is multivariate data analysis; Basic concepts in MV – variate, measurement error; Power analysis and effect size; SPSS software

Unit 2: Classification and Types of MVSM

Independence and dependence techniques; Factor analysis – principal component, exploratory factor analysis; Multiple correlation and multiple regression; Discriminant analysis; Logistic regression; Cluster analysis; Conjoint analysis; Multi Dimensional Scaling/ Perceptual mapping; Correspondence analysis; Structural equation model

Unit 3: Selecting Appropriate MVSM

Selection based on purpose - Dimension reduction, identifying latent variables, strength of relationship among multiple dependent/ independent variables, identifying choice and estimating their utility; etc and type of variables – metric and non-metric

Unit 4: A Structured Approach for Building Multivariate Statistical Models

Steps in planning and conducing MVSM

Unit 5: Basic Econometric Methods-1

Nature of regression analysis; Two variable and multivariable regression models; Linear and non-linear regression models; Estimation methods

Unit 6: Basic Econometric Methods-2

Simultaneous-equation models; Panel data models; **Forecasting** - Time series and other models

Block 2: Data Preparation and Cleaning

Unit 1: Missing Data Analysis and Outlier Management

Missing data - Meaning, types, methods of missing data processing, advantages and limitations, **Outliers-** Meaning, types, methods for identifying and managing outliers

Unit 2: Testing Assumptions of MVSM and Data Transformation

Testing assumption of parametric analyses – normality, linearity, multicollinearity; Data transformation methods

Block 3: Methods for Assessing Human Choice/ Preferences and Decision-making

Unit 1: Assessing Human Preference Structures Using Conjoint Analysis

Meaning- Importance, guidelines for selecting variables, steps in designing a conjoint experiment – objectives, design, data collection and analysis. Applications in extension

Unit 2: Assessment of Adoption of Agricultural Technologies Using Limited Dependent Variable Models

Meaning, importance, types – logit, probit and tobit and their variations; steps in analysis and interpretation of results, applications in extension

Unit 3: Multidimensional Scaling

Meaning, importance and types, steps and applications in extension

Unit 4: Multi-criteria decision-making

Meaning, importance, methods – analytical hierarchy process, Applications in extension

Block 4: Methods of Assessing Association and Causality

Unit 1: Multiple Correlations and Multiple Regressions

Meaning, importance, types, methods of estimation, analysis and interpretation of results, application sin extension

Unit 2: Discriminant Analysis

Meaning, types, steps in conducting discriminant analysis, Applications in extension

Block 5: Methods Of Grouping Objects/ Variables Based On Latent Variables

Unit 1: Principal Component Analysis (PCA) and Common Factor Analysis

Meaning, importance, types of factor analysis, difference between types, steps in conducting PCA/ Common Factor Analysis, applications in extension

Unit 2: Structural Equation Modelling (SEM) – Two units

Meaning, importance, types – confirmatory factor analysis and structural model; steps in conducting SEM, Applications in extension

Unit 3: Cluster Analysis

Meaning, importance, types – Steps; Applications in extension

Block 6: Emerging MV Statistical Methods

Unit 1: Emerging MV Statistical Methods

Canonical correlation, partial least square (PLS)

VIII. Practicals

- Hands on experience of following methods using SPSS/ AMOS software
- Selecting appropriate MVSM
- Missing data analysis and outlier management
- Testing assumptions of MVSM and data transformation
- Assessing human preference structures using conjoint analysis
- Assessment of adoption of agricultural technologies using limited dependent variable models – logit, probit and tobit.
- Multidimensional scaling
- Multiple correlation and multiple regression
- Discriminant analysis
- Principal Component Analysis (PCA) and Common Factor Analysis
- Structural Equation Modeling (SEM)
- Cluster analysis

IX. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work
– Guest Lectures

X. Suggested Reading

Agresti, A. 2002. *Categorical data analysis*. Second edition. New York, NY: John Wiley & Sons.

Belsley, D. A. 1991. *Conditioning diagnostics: Collinearity and weak data in regression*. New York, NY: Wiley.

Bollen, K.A. 1989. *Structural equations with latent variables*. New York: John Wiley and Sons.

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Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Social Sciences
– Agri-Business Management

Preface

Rapid advancement in agriculture has resulted in increased demand for qualified managers to manage this sector. Indian agriculture is facing numerous challenges with a rapidly changing business environment, pace of technological change, globalisation, competitive environment and changing role of government. These challenges will place unparalleled demands on the capabilities of tomorrow's managers. Agribusiness Management has enormous potential to address key national and global challenges of inclusive growth, and food and nutritional security. With increasing incomes, the demand for value added agricultural products will also increase, driving the demand for Agribusiness Managers. Increasing integration of World food markets and the expansion of organized retail also imply that the scope of agribusiness is becoming increasingly global. The Agribusiness Management Education System in India is uniquely placed to meet the demand for professional agribusiness managers across the globe.

Agri business management is a specialized two-year MBA programme which focuses on business aspect of agriculture production and its international trade. The postgraduate course aims to craft professional business leaders and entrepreneurs in food, agriculture and allied sectors. The course is offered in premier business schools in and State Agricultural Universities in India and across the globe and focuses on managerial skill development in the agricultural sector. Students learn how to make sustainable business decisions and minimize risk while working in the agricultural sector. The course curriculum is designed to build and enhance a global perspective among students. The course also needs to create awareness among students about the environmental forces that impact managerial decisions.

In light of the above mentioned issues and concerns, courses and programmes in the field of agri-business management must also be reformed to increase the employability and entrepreneurship opportunities for the Post Graduates and Doctoral participants at the same time prepare them for handling global competitiveness without compromising farmers' and farming community needs and demands.

The sub-committee on Agri Business Management constituted by ICAR (under the ICAR Broad Subject Matter Area (BSMA) for Social Sciences) has kept above development in view while revising the PG and PhD Curricula in Agri Business Management. We also addressed the issue of repetitions of content, updating them with the recent trends in the industry, under-graduate curricula in agriculture. To do these, we identified first the core competencies that are required at the different levels and worked backwards based on the areas and organising them into courses.

We are also recommending summer internship-2 at the Master's level (each for 4-6 weeks with agri based organisations) and we propose a credit load of 10 and 4 for each of these internships/ attachments at PG level. We believe this will help the students to have more relevant practical experience and this will boost their job prospects.

We have organised the curriculum under different block and units and each course has an introduction explicitly stating the purpose of this course (why this course), aim of the course (what it tries to provide) and learning outcomes. Several new reading references are also provided at the end of each course. The committee recognised the need for organising training of teachers to impart some of the new courses and this could be further elaborated in consultation with ICAR and other organisations that can support or even lead this exercise.

The committee organised a stakeholders meeting with agri based industry executives, academicians from reputed institutions, alumni from different ABM programmes of the SAUs, teachers involved in ABM teaching in selected SAUs at Bikaner on September 17, 2018 for development of curricula.

Our heartfelt gratitude to all the core committee members and stakeholders for their specific contributions to development of this revised curricula especially Mr Kamal Kumar, Advisor, Dhanuka Agritech Ltd; Dr Vikram Singh, Dean, NIAM, Jaipur; Dr Ranjit Singh, Professor, NAARM; Dr Seema Nath, Associate Dean, College of Agriculture, PJTSAU; Dr Radhika, Associate Professor, PJTSAU; Dr Madhu Sharma, Professor, SKRAU, Bikaner, Dr Swati Sharma, Assistant Professor, Navsari Agricultural University, Navsari; Dr Dinesh Jain, Associate Professor, RAJUVAS, Bikaner and Dr Amita Sharma, Assistant Professor, IABM, Bikaner.

Finally, we thank Dr NS Rathore, Deputy Director General (Education), ICAR for organising the BSMA for undertaking curricula revision and for his valuable guidance and support in this regard.

Dr Samarendra Mahapatra, Member
Dr Aditi Mathur, Member
Dr Lipi Das, Convener
Dr Kalpana Sastry, Chairperson

May 31, 2019

Course Title with Credit Load
MBA in Agri-Business Management

Major Courses 20 Credits

Course Code	Course Title	Credit Hours
ABM 501	Principles of Management and Organisational Behaviour	3
ABM 502	Managerial Accounting and Control	3
ABM 503	Applied Agribusiness Economics	2
ABM 504	Human Resource Management for Agricultural Organizations	2
ABM 505	Production and Operations Management	2
ABM 506	Agricultural and Food Marketing Management- I	2
ABM 507	Agricultural and Food Marketing Management- II	2
ABM 508	Agri Supply Chain Management	2
ABM 509	International Trade for Agricultural Products	2

Minor Courses 8 Credits

It is suggested the student may choose at least four courses out of the courses listed below as part of minor courses as these are related to specific areas of agri business and aim to build larger understanding of the subject. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/HoD.

Course Code	Course Title	Credit Hours
ABM 510	Food Technology and Processing Management	3
ABM 511	Rural Marketing	3
ABM 512	Fertiliser Technology and Management	3
ABM 513	Management of Agro-Chemical Industry	3
ABM 514	Seed Production Technology Management	3
ABM 515	Technology Management for Livestock Products	3
ABM 516	Fruit Production & Post Harvest Management	3
ABM 517	Farm Power & Machinery Management	2
ABM 518	Food Retail Management	2
ABM 519	Management of Agricultural Input Marketing	2
ABM 520	Feed Business Management	2
ABM 521	Management of Veterinary Hospitals	2
ABM 522	Poultry And Hatchery Management	2
ABM 523	Management Of Floriculture And Landscaping	2
ABM 524	Risk Management In Agri Business	2
ABM 525	Management Of Agri-Business Co-Operatives	2

Course Code	Course Title	Credit Hours
ABM 526	Business Analytics for Agriculture	2
ABM 527	Dairy Business Management	1
ABM 528	Agri Extension Management	1
ABM 529	Renewable Energy Sources Management	1
ABM 530	Quality Management for Agri Business	1
ABM 531	Advertising And Brand Management	1
ABM 532	Agri Infrastructure and Warehousing Management	1
ABM 533	Contract Farming	1
ABM 534	Human Resource Competence And CapacityBuilding Systems	1
ABM 535	Agri Commodity Markets And Futures Trading	1

Supporting Courses 6 Credits

Course Code	Course Title	Credit Hours
ABM 536	Strategic Management for Agri Business Enterprises	2
ABM 537	Operations Research	2
ABM 538	Financial Management in Agri Business	2

Common Courses 5 Credits

1. Technical Writing and Communications Skills
2. Intellectual Property and its management in Agriculture
3. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/MOOCs. The students may be allowed to register these courses/similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/she may be permitted to register for other related courses with the prior approvalof the HoD/BoS.

Master's Seminar 01 Credit

Course Code	Course Title	Credit Hours
	Research (Summer Internship + Research Project)	**30 (10+20)**
	Summer Internship/ Industrial Attachment	4
	Basic Courses mandatory for Summer Internship	6
ABM 539	Communication for Management and Agri Business	3
ABM 540	Research Methodology for Agri Business Mgmt	3
	Research Project	**20**
	Project work	**10**
	Basic courses mandatory for Project	10

Course Code	Course Title	Credit Hours
ABM 541	Computer Applications for Agri Business	3
ABM 542	Project Management and Agri Business Entrepreneurship	3
ABM 543	Agribusiness Environment and Policy	2
ABM 544	Agri Business Laws and Ethics	2

Course Contents
MBA in Agri-Business Management

I. Course Title : Principles of Management and Organizational Behaviour

II. Course Code : ABM 501

III. Credit Hours : 3+0

IV. Aim of the course

Provide students with opportunities to understand a wide variety of topics related to business management, focusing on fundamental management principles and concepts that apply to agribusiness, traditional management skills, and new competencies needed to succeed in a fast-paced environment that demands ongoing innovations.

The course is organized as follows:

No	Blocks	Units
1.	Basic Concepts of Management	1. Introduction to Management 2. Planning, Organising, Directing and Controlling
2.	Insights about Organisational Behaviour	1. Foundations of Individual behaviour 2. Group Dynamics
3.	Organisational Dynamics	1. Understanding and managing organisational culture 2. Concept of Organisational Development

V. Theory

Block 1: Basic Concepts of Management

Unit-I: Introduction to Management: Nature, Scope and Significance of Management, Evolution of Management Thought, Approaches to Management, functions and skills of a manager

Unit-II: Management functions: Planning – Types, Steps, Objective, Process, Strategies, Policies, MBO, Organizing – Structure & Process, Line, Staff, Authority & Responsibility, Staffing – Recruitment and Selection, Directing – Training, Communication & Motivation, Controlling- Significance, Process, Techniques, Standards & Benchmarks, Management Audit

Block 2: Insights About Organizational Behavior

Unit III: Nature, Scope and Significance of Organizational Behavior; Foundations ofIndividual behaviour – Emotions, Personality, Values, Attitudes, Perception, Learning and individual decision making, Motivation- Types of motivation, theories of motivation, motivational practices at workplace, managing stress and work life balance

Unit IV: Group dynamics- types of groups, group formation, Group decision making, teambuilding and developing collaboration, leadership styles and influence process;

leadership theories, leadership styles and effective leader

Block 3: Organisational Dynamics

Unit V: Understanding and managing organisational culture, power and political behavior inorganisations, conflict Management, negotiation, managing organizational change, concept of organisational development

VI. Teaching methods/activities

- Interactive Lectures
- Assignment (Reading/Writing)
- Student presentations
- Case study related to basics of management and organizational behaviour

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic concepts of management and organizational behaviour
- Develop a overall view about the various management functions, managerial skills and approaches
- Get insights about the fundamentals of individual and group behavior in the orgnisational setting
- Analyse the organisational level challenges in managing the resources optimally

VIII. Suggested Reading

- Robbins SP, Coulter M and Vohra N. 2010. *Management*. Pearson Edu.
- Weihrich H, Cannice MV and Koontz H. 2015*, Management, A Global, Innovative and Entrepreneurial Perspective,* 14th Edition, McGraw Hill Education Pvt Ltd.
- Beierlein JG, Schneeberger KC, Osburn DD. 2014. *Principles ofAgribusiness Management*. Fifth edition. Waveland Press
- Neck CP, Houghton JD and Murray EL. 2017, *Organizational behavior*, Sage Publication India Private Limited.
- Greenberg J. 2013, *Behavior in Organisations*, PHI Learning Private Limited, New Delhi.
- John A, Wagner III JA and Hollenbeck JR. 2015. *Organizational Behaviour*, Routledge Taylor & Francis Group, New York.
- Koontz H and Weighhrich K. 2010. *Essentials of Management*. Tata McGraw Hill

I. Course Title : Managerial Accounting and Control

II. Course Code : ABM 502

III. Credit Hours : 3+0

IV. Aim of the course

The objective of this course is to expose the learner to the concept and methods of financial and management accounting. Focus will be on understanding techniques, uses and applications of financial and management accounting.

No	Blocks	Units
1.	Financial Accounting	1. Introduction to financial accounting 2. Accounting standards 3. Double Entry system 4. Use of accounting softwares
2.	Managerial Accounting	1. Meaning of Managerial accounting 2. Analysis of financial statements 3. Cash flow and fund flow analysis

No	Blocks	Units
3.	Cost Accounting	1. Introduction to cost accounting 2. Standard costing 3. Variance Analysis 4. Budget and budgetary control

V. Theory

Block 1: Financial Accounting

Unit I: Financial Accounting- Meaning, Need, Accounting principles: Accounting Conceptsand Conventions; Branches of Accounting, Users of Accounting information, Advantages and Limitations of Financial Accounting, Accounting Standards

Unit II: The Double Entry System- Its Meaning and Scope, The Journal, Cash Book, Ledger, Trial Balance, Trading Account Profit and Loss Account, Balance Sheet, entries and adjustments of different heads in different Books and Accounts, Introduction of Company Accounts, Use of Accounting Software

Block 2: Managerial Accounting

Unit III: Management Accounting-Meaning, Functions, Scope, Utility, Limitations and Toolsof Management Accounting, Analysis of Financial Statements- Ratio, time series, common size and Du pont Analysis, Comparative and Common Size Statements, Cash Flow and Fund Flow Analysis

Block 3: Cost Accounting

Unit IV: Cost Accounting–Nature, Course, Significance of Cost Accounting; Classification ofCost, Costing for Material; Labour and overheads; Marginal Costing and cost volume profit Analysis- Its Significance, Uses and Limitations; Standard Costing – Its Meaning, Uses and Limitations, Determination of Standard Cost, Variance Analysis-Material, Labour and Overhead.

Unit V: Budget and Budgetary Control- Meaning, Uses and Limitations, Budgeting and Profitplanning, Different Types of Budgets and their Preparations: Sales Budget, Purchase Budget, Production Budget, Cash Budget, Flexible Budget, Master Budget, Zero Based Budgeting. Mergers and Acquisition, Tax System- GST

VI. Teaching methods/activities

- Lecture
- Case studies for making the participants get a clear idea about the real life budgeting and accounting practices
- Live project in the firms finance departments for getting the first hand experience

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Develop a clear understanding about the concepts of financial and managerial accounting
- Understand the basics of cost accounting through various tools and techniques available
- Get a insight about the budget and budgetary control methods

VIII. Suggested Reading

- Jain SP and Narang KL. 2014. *Financial Accounting*. 12th Edition. Kalyani publisher

- Sharma and Gupta. 2018. *Management Accounting* 13th Edition, Kalyani Publisher
- Maheshwari SN and Maheshwari SK. 2018. *Financial Accounting*. 6th Ed. Vikas Publ. House.

I. Course Title : Applied Agribusiness Economics

II. Course Code : ABM-503

III. Credit Hours : 2+0

IV. Aim of the course

This course applies basic economic tools and models to problems involving supply, demand, individual consumer and firm behavior, and market structure. Basic market structure models covered include perfect competition, monopolistic competition, oligopoly, and monopoly. Economic tools and models are related to business strategies throughout the course.

The course is organized as follows:

No	Blocks	Units
1.	Overview of Managerial Economics	1. Basic managerial economics principles 2. Mathematical concepts used in managerial economics 3. Introduction to behavioral economics
2.	Production, cost and supply analysis	1. Production Function 2. Cost Concepts 3. Determinants of price
3.	Macroeconomics	1. The national income 2. Flow of money in the market and economy 3. Business decisions under certain and uncertain situations

V. Theory

Block 1: Overview of Managerial Economics

Unit I: Scope of managerial economics, objective of the firm and basic economic principles; mathematical concepts used in managerial economics. Introduction to behavioral economics

Unit II: Indifference curves and budget sets - Demand analysis - meaning, types and determinants of demand; demand function; demand elasticity; demand forecasting-need and techniques.

Block 2: Production, Cost and Supply Analysis

Unit III: Production, cost and supply analysis- production function, Multi period productionand cost least-cost input combination, factor productivities and returns to scale, cost concepts, cost-output relationship, short and long-run supply functions.

Unit IV: Pricing-determinants of price - pricing under different market structures, pricing ofjoint products, pricing methods in practice, government policies and pricing. Price discrimination (First, Second and Third level)

Block 3: Macroeconomics

Unit V: The national income; circular flow of income: consumption, investment and saving: money-functions, factors influencing demand for money & supply of money; inflation; economic growth; business cycles and business policies; business decisions under certain and uncertain situations

VI. Teaching methods/activities

- Interactive Lectures
- Assignment (Reading and Writing)
- Cases on recent developments in economic environment
- Live projects to understand the principles of economics for an organisation
- Group analysis of newspapers covering national level economic trends

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the concepts of managerial economics and its implications on the agri business environment
– Develop a clearer overview on the macroeconomic environment that exists for a agri business enterprise to understand and adapt for optimizing the output

VIII. Suggested Reading

- Dwivedi DN. 2015. *Managerial Economics*. 8th Edition, Vikash Publishing
- Gupta GS. 2015. *Managerial Economics*. Tata McGraw Hill
- Savatore D. Srivastav R. 2012. *Managerial Economics*. 7th Edition, Oxford University Press
- Suma Damodaran. 2010. *Managerial Economics*. Oxford

I. Course Title : Human Resource Management for Agricultural Organisations

II. Course Code : ABM 504

III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to expose the learner to the field of human resource management. The focus will be on human resource practices and their utility for managers in agri based organizations.

The course is organized as follows:

No	Blocks	Units
1	Overview of Human Resource Management	1. Meaning and scope of Human Resource Management 2. Human Resource Planning 3. Recruitment, Selection and Training 4. Performance Appraisal 5. Compensation Management
2	Industrial Relations	1. Trade Union 2. Grievance Management 3. Health and Safety of HR
3	Ethical and Global issues in HRM	1. Global HRM 2. HR Metrics, HRIS and workplace analystics

V. Theory

Block 1: Introduction to Human Resource Management

Unit I: Strategic Human Resource Management, Human Resource Planning-Nature andSignificance, Job Analysis and talent management process, Job Description, job Specification, Job enlargement, Job enrichment, Job rotation

Unit II: Recruitment and Selection Process, Induction, Training and Human Resource Development-Nature, Significance, Process and Techniques, e- recruitment, use of Big Data for recruitment, use of Artificial Intelligence and machine learning tools in recruitment practices Career planning and Development Internal mobility including Transfers, Promotions, employee separation.

Unit III: Performance Appraisal–Significance and methods, Compensation management, Strategic pay plans, Job Evaluation, Wage and Salary Administration; Wage Fixation; Fringe Benefits, Incentive Payment, bonus, and Profit Sharing

Block 2: Industrial Relations

Unit IV: Role and Status of Trade Unions; Collective Bargaining; Worker's Participation inManagement, employee retention. Quality of work life, employee welfare measure, work life balance, Disputes and Grievance Handling Procedures; Arbitration and Adjudication; Health and Safety of Human Resources;

Block 3: Ethical And Global Issues In Hrm

Unit V: Ethical issues in HRM**,** Managing Global Human Resources, Managing Human Resources in Small and Entrepreneurial firms, Human Resources accounting, Human Resources outsourcing. HR Information System, Human Resource Metrics and Workforce Analytics, Future trends in workforce technologies.

VI. Teaching methods/activities

- Lectures
- Videos showing trends and practices of innovative human resource management
- Live project for understanding the application of concepts in the real life situation
- Interaction with the HR managers of the agri based organsiations to understand the intricacies involved in the managing the human resource
- Group tasks to study the policy framework and regulatory environment that exists in India and globally to manage human resource

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basic concept of HRM and SHRM
– Develop an insight into important human resource management functions like job analysis, job planning, recruitment, selection, performance appraisal, training, development, compensation management etc with major reference to the agri based organisations
– Get a clearer view about the status of employee – employer relationship in Indian agri enterprises and global agri based organizations
– Understand the ethical and recent trends in managing human resource effectively

VIII. Suggested Reading

- Gary Dessler & Biju Varkkey 2016, *Human Resource Management*, XIV Edition, Pearson India
- VSP Rao. 2010, *Human Resource Management, Text and Cases,* 3rd Edition, Excel Books
- Ashwathapa K. 2016. *Human Resource Management, Text and Caes*. Tata McGraw Hill
- Michael J. Kavanagh, Mohan Thite & Richard D. Johnson. 2016, *Human ResourceInformation Systems*, Sage Publications
- Subba Rao P. 2004. *Essentials of Human Resource Management and Industrial Relations*. Himalaya Publ. House.

I. Course Title : Production and Operations Management

II. Course Code : ABM 505

III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to expose the learner to the field of production and operations management. The focus will be on imparting knowledge of the basic concepts, tools, and functions of production management.
The course is organized as follows:

No	Blocks	Units
1	Introduction to Production and Operations Management	1. Concept and scope of production and operations management 2. Operations strategy 3. Productivity variables and measurement
2	Inventory management	1. Determination of material requirement 2. Industrial safety 3. Cloud operations management
3	Overview of Quality Management	1. Statistical process control 2. Reengineering and Value engineering

V. Theory

Block 1: Introduction to Production and Operations Management

Unit I: Nature Concept and Scope of Production and Operations Management; FactorsAffecting System; Facility location, Types of Manufacturing Systems and Layouts, Process Selection and Facility Layout, Layout Planning and Analysis, Forecasting

Unit II: Operations Strategy: Operations Strategy, Competitive Capabilities and CoreCompetencies, Operations Strategy as a Competitive Weapon, Linkage Between Corporate, Business, and Operations Strategy, Developing Operations Strategy, Elements or Components of Operations Strategy, Competitive Priorities, Manufacturing Strategies, Service Strategies, Global Strategies and Role of Operations Strategy.

Unit III: Productivity Variables and Productivity Measurement, Production Planning andControl, Mass Production, Batch Production, Job Order Manufacturing, Product Selection, Product Design and Development, Process Selection, Capacity planning.

Block 2: Inventory Management

Unit IV: An Overview of Inventory Management Fundamentals, Determination of MaterialRequirement, Safety Management Scheduling, Maintenance Management Concepts, Work Study, Method Study, Work Measurement, Work Sampling, Work Environment, Production Planning and Control (PPC) Industrial Safety, human-machine interface, types of interface designs. Cloud operations management

Block 3: Quality Management

Unit V: Quality Assurance, Accepting Sampling, Statistical Process Control, Total QualityManagement, ISO standards and their Importance, Introduction to re-engineering, value engineering, check sheets, Pareto charts, Ishikawa charts, JIT Pre-requisites for implementation Six Sigma, Lean Management, Reliability

Engineering, Safety Engineering, Fault Tree Analysis.

VI. Teaching methods/activities

- Interactive sessions
- Live projects
- Assignments (reading and writing)
- Presentations of quality management practices by leading agri and food organizations

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basic concepts of production and operations management including manufacturing systems, layout planning and analysis
– Develop a understanding about the operations strategy, productivity variables, and their measurement along with product design and development
– Get an insight about fundamentals of inventory management, safety management, quality assurance practices and techniques with major emphasis on agri and food based industries

VIII. Suggested Reading

- William J. Stevenson. 2014. *Operations Management*, 12th Edition, McGraw-Hill
- Panneerselvam K. 2012. *Production and Operations Management* 3rd Edition, Prentice Hall India Learning Private Limited
- S. N Chary, 2017. *Production and Operations Management*, McGraw Hill Education; 5 edition

I. Course Title : Agricultural And Food Marketing Management-I

II. Course Code : ABM 506

III. Credit Hours : 2+0

IV. Aim of the course

To develop the understanding the concept of marketing system with specific inputs of product, pricing, availability and promotional details

The course is organized as follows:

No	Blocks	Units
1.	Marketing concept	1. Overview of Marketing Management 2. Developing the product mix 3. Branding decisions 4. Packaging technology
2	Pricing decisions	1. Pricing Objectives 2. Types of pricing
3	Channel Management and Physical Distribution	1. Distribution channels 2. Warehouse management, Inventory management 3. Transport management
4	Marketing Communications	1. Marketing communications mix 2. Digital Marketing, Mobile Marketing, Social Marketing and Social Media Marketing 3. Marketing efficiency and effectiveness

V. Theory

Block 1: Overview Of Marketing Management

Unit 1: Introduction and Concept/ philosophies of Marketing Management; Product Management: The product, The product mix, Product line extensions, Product linedeletions, Branding products, The advantages and disadvantages of branding, Branding decisions Brand loyalty models, Homogenous first-order markov models, Higher-order markov models Packaging, The functions of packaging, Packaging technology, Recent developments in packaging

Block 2: Pricing Decisions

Unit 2: Pricing objectives, The laws of supply and demand, Elasticity of demand Cross-price elasticity of demand, Practical problems of price theory, Cost - revenue - supply relationships, The meaning of price to consumers, Price as an indicator of quality, Pricing strategies, Cost-plus methods of price determination, Breakeven analysis, Market-oriented pricing, Psychological pricing, Geographical pricing, Administered pricing

Block 3: Channel Management and Physical Distribution

Unit 3: Channel decisions in relation to marketing strategy, The value of middlemen, Key decisions in channel management, Types of distribution system, Marketing to middlemen, Power and conflict in distribution channels, Physical distribution, Customer service levels, Developing a customer service policy, The total distribution concept, Warehouse management, Inventory management, Calculating the economic order quantity, Transport management, Technological advances in physical distribution, Vehicle scheduling and routing, Fixed and variable routing systems, Vehicle scheduling tools, Vehicle scheduling models, Computer-based vehicle scheduling

Block 4: Marketing Communications

Unit 4: The nature of marketing communications, Setting marketing communication objectives, Factors influencing the communications mix, The marketing communications mix, Advertising, Sales promotion, Public relations, Personal selling, Digital Marketing, Mobile Marketing, Social Marketing and Social Media Marketing, Training the sales force, Change agents, Selecting the media, Establishing the promotional budget, Monitoring the effectiveness of marketing communications

Unit 5: Marketing Costs And Margins: Assessing the performance of a marketing system, Marketing efficiency and effectiveness, Operational efficiency, Pricing efficiency, Identifying marketing costs and margins, The reference products concept, Handling costs, Packaging costs, Transport costs, Storage costs, Processing costs, Capital costs

VI. Teaching methods/activities

- Lectures
- Cases studies from recent marketing trends from the agri and food organisations
- Assignments (Group/ Individual)
- Live project based upon marketing practices adopted by various organizations
- Group discussions on contemporary marketing practices

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basics of marketing with specific emphasis on managing the product details
– Get detailed insight on the pricing techniques and managing the demand and supply relationship profitably
– Develop the understanding about the marketing channels and intermediaries involved
– Understand the promotional strategies and communication development tools and methods

VIII. Suggested Reading

- Kotler P, Keller K, Koshy A and Jha M. 2013. *Marketing Management–Analysis, Planning, Implementation and Control*. Pearson Education.
- Ramaswamy VS. 2017. *Marketing Management: A Strategic Decision Making Approach*
- McGraw Hill Education
- Saxena R. 2009. *Marketing Management*. Mc Graw Hill.4th Edition
- William Perreault Jr., Mccarthy E. Jerome., 2006, *Basic Marketing: A Global Marketing Approach,* Tata McGraw Hill
- Gay R, Cjarlesworth A, Esen R. 2014, *Online Marketing*, Oxford University Press
- Mohammed, Fisher, Jaworski and Cahill: *Internet Marketing – Building Advantage in a networked economy* Tata McGraw-Hill
- Strauss J and Frost R. 2013. *E-Marketing*, Prentice-Hall
- Roberts M. 2018. *Internet Marketing*, Cengage Learning
- Vassos: *Strategic Internet Marketing – Practical e-commerce and branding Tactics*, Que Books
- Chaffey, Meyer, Johnston and Ellis – Chadwick. 2009. *Internet Marketing*, Prentice-Hall/ Financial Times

I. Course Title : Agricultural and Food Marketing Management-II

II. Course Code : ABM 507

III. Credit Hours : 2+0

IV. Aim of the course

To develop learning about the basic concept of marketing with major emphasis on agri and food marketing by equipping the students with the understanding of ecosystem in which the agri organization functions to meet the requirements of the customer profitably

The course is organized as follows:

No	Blocks	Units
1.	Agricultural and Food Marketing	1. Marketing concept and marketing systems 2. Market Liberalisation
2.	Marketing Strategy, Planning and Control	1. Marketing planning 2. New Product Development:
3.	Commodity Marketing	1. Grain marketing, 2. Livestock and meat marketing, 3. Poultry and eggs marketing, marketing of fresh milk

V. Theory

Block 1: Agricultural and Food Marketing

Unit 1: The importance of agricultural and food marketing to developing countries,

the marketing concept and marketing systems, Marketing sub-systems
Marketing functions, Links between agriculture and the food industry, Agricultural and food marketing enterprises, Marketing boards in developing countries, Co-operatives in the agriculture and food sectors, Control and management of secondary co-operatives, The weaknesses of co-operatives, Selling arrangements between co-operatives and their members

Unit 2: Market Liberalisation: Economic structural adjustment programmes, Macro-economicstabilisation, The role of the state in liberalised markets, Strategies for reforming agricultural marketing, Obstacles to be overcome in commercialisation and Privatisation of agricultural marketing, Dealing with accumulated deficits, Encouraging private sector involvement in agricultural marketing, Impediments to private sector participation in agricultural markets, impact of the macro-economic environment on private traders, Government action to improve private sector performance

Block 2: Marketing Strategy, Planning and Control

Unit 3: Marketing Strategy, Planning and Control: Strategy, policy and planning, Strategic businessunits, The need for marketing planning, The process of marketing planning, Contents of the marketing plan, Monitoring, evaluating and controlling the marketing planning, Marketing controls, Marketing plan control, Efficiency control

Unit 4: New Product Development: The impetus to innovation, New product development process
The adoption process, The effect of products characteristics on the rate of adoption, Buyer behavior: The influences on buyer behaviour, Exogenous influences on buyer behaviour Endogenous influences on buyer behaviour, The consumer buying decision process, Buyer behaviour and market segmentation, Lifestyle segmentation, Organisational markets Industrial markets, Industrial buyer characteristics

Block 3: Commodity Marketing

Unit 5: Stages in a commodity marketing system, Grain marketing, Challenges for grain marketing systems, fruits and vegetables, Livestock and meat marketing, Poultry and eggs marketing, marketing of fresh milk

VI. Teaching methods/activities

- Lectures
- Cases studies from recent marketing trends from the agri and food organisations
- Assignments (Group/ Individual)
- Live project based upon marketing practices adopted by various organizations
- Group discussions on contemporary marketing practices

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the agricultural and food marketing concepts and systems
- Get an insight about the marketing planning and strategies for developing products for meeting the specific needs of the final customers
- Develop a clear view about the commodity marketing practices in India and in International markets

VIII. Suggested Reading

- Acharya SS and Agarwal NL. 2011. *Agricultural Marketing in India*. 4th Ed. Oxford and IBH.

- Kohls RL and Uhj JN. 2005. *Marketing of Agricultural Products*. 9th Ed. Prentice Hall.
- Mohan J. *Agri-Marketing Strategies in India*, NIPA
- Sharma Premjit. 2010. *Agri-Marketing Management*, Daya Publishing House

I. Course Title : Agri Supply Chain Management

II. Course Code : ABM 508

III. Credit Hours : 2+0

IV. Aim of the course

To introduce the students to the concepts, processes and framework of agricultural supply chain management.

The course is organized as follows:

No	Blocks	Units
1	Overview of Supply Chain Management	1. Introduction to Agri Supply Chain Management 2. Demand Management in Supply Chain 3. Manufacturing Management
2	Procurement Management	1. Purchasing Cycle 2. Material Requirement Planning
3	Logistics Management	1. Distribution Strategies and Management 2. Warehouse Management 3. IT application in ASCM

V. Theory

Block 1: Overview Of Supply Chain Management

Unit I: Supply Chain: Changing Business Environment; SCM: Present Need; ConceptualModel of Supply Chain Management; Evolution of SCM; SCM Approach; Traditional Agri. Supply Chain Management Approach; Modern Supply Chain Management Approach; Elements in SCM. Innovations in Global Agri-SCM

Unit II: Demand Management in Supply Chain: Types of Demand, Demand Planning andForecasting; Operations Management in Supply Chain, Basic Principles of Manufacturing Management. SCM Metrics/Drivers and Obstacles.

Block 2: Procurement Management in Agri. Supply Chain

Unit III: Purchasing Cycle, Types of Purchases, Contract/Corporate Farming, Classification ofPurchases Goods or Services, Traditional Inventory Management, Material Requirements Planning, Just in Time (JIT), Vendor Managed Inventory (VMI).

Block 3: Logistics Management

Unit IV: History and Evolution of Logistics; Elements of Logistics; Management; Distribution Management, Distribution Strategies; Pool Distribution; Transportation Management; Fleet Management; Service Innovation; Warehousing; Packaging for Logistics, Third-Party Logistics (TPL/3PL); GPS Technology.

Unit V: Concept of Information Technology: IT Application in SCM; Advanced Planning andScheduling; SCM in Electronic Business; Role of Knowledge in SCM; Performance Measurement and Controls in Agri. Supply Chain Management-Benchmarking: introduction, concept and forms of Benchmarking. Case Studies on the following: (a) Green Supply Chains (b) Global Supply Chains (c) Coordination in a SC. Value of and distortion of information: Bullwhip effect (d) Sourcing and contracts in SC (e) Product availability with uncertain demand (f) Inventory planning with known/ unknown demand (g) Cases from FAO/IFPRI, etc.

VI. Teaching methods/activities

- Lectures
- Case study on the real life situations regarding the supply chain management practices
- Assignments (Group and individual)
- Live projects
- Newspaper analysis
- Presentations of best practices in the industry
- Videos and guest lectures by the eminent and successful organizations

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the various elements involved in managing agri supply chain from farm to fork
– Relate well with the issues and challenges involved in managing and forecasting the demand of the products
– Develop insights on the techniques of procurement management and handling inventory
– Assess the importance of managing logistics along with adequate handling and packaging intricacies
– Get a overall clarity about the use of information technology to make the agri supply chain more efficient and rewarding

VIII. Suggested Reading

- Acharya SS and Agarwal NL. 2011. *Agricultural marketing in India*. Oxford and IBH.
- Altekar RV. 2006, *Supply Chain Management: Concepts and Cases*. PHI
- Chopra S, Meindl P and Kalra DV. 2016. *Supply chain management: Strategy, Planning, and Operation*, Pearson Education India
- Mohanty RP. 2010. *Indian Case studies in Supply Chain Management & other Learning Resources*. Oxford.
- Chandrasekaran N. 2010. *Supply Chain Management: Process, system & Practice*. Oxford.
- Singh S. 2004. *Organic Produce Supply Chains in India-Organisation and governance*. Allied Publ.

I. Course Title : International Trade in Agricultural Products

II. Course Code : ABM 509

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge to the students about international trade in agriculture and various provisions under WTO in the new trade regime.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to International Trade	1. Basic concepts of International Trade 2. WTO and its implications for Indian agri business sector 3. International trade restrictions and support systems
2.	Regulations and policy measures for International trade	1. India's foreign trade policy framework 2. Market entry methods 3. Export procedures & documentations

V. Theory

Block 1: Introduction To International Trade

Unit I: International trade–basic concepts, WTO and its implications for Indian economy ingeneral and agriculture sector in particular.

Unit II: TRIPS, TRIMS quotas, anti dumping duties, quantitative and qualitative restrictions, tariff and non-tariff measures, trade liberalization, subsidies, green and red boxes, issues for negotiations in future in WTO; CDMs and carbon trade.

Unit III: Importance of foreign trade for developing economy; absolute and comparativeadvantage, foreign trade of India. Cases on agri business commodity trade practices

Block 2: Regulations and Policy Measures for International TRADE

Unit IV: India's balance of payments; inter regional Vs international trade; tariffs andtradecontrol; exchange rate; the foreign trade multiplier.

Unit V: Foreign demand, supply side analysis, opportunity cost, trade and factor prices, implications for developing countries, market entry methods, export procedures & documentations.

VI. Teaching methods/activities

- Lectures
- Cases on contemporary issues
- Group assignments
- Live projects
- Policy discussions
- Guest lectures
- Industrial visits to firms exporting agri commodities

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic concepts of International trade with reference to WTO and International agreements on Agriculture
- Assess the practices of trade of agri business commodities
- Develop a clear understanding about the significant regulations and policy measures for International Trade

VIII. Suggested Reading

- Study materials by the Center for WTO Studies, ITPO, New Delhi, *The Future of Indian Agriculture*

- Brouwer F and Joshi PK. 2016. *International Trade and Food Security*, LEI - Wageningen UR, The Netherlands.

I. Course Title : Food Technology and Processing Management

II. Course Code : ABM 510

III. Credit Hours : 3+0

IV. Why this course?

As a discipline, Food Technology is the combination of engineering, food science, hotel management, and home science. It is an advanced study of the technology and processing methods used to develop, research, manufacture, produce, preserve and process food with related substances.

V. Aim of the course

Food Technology is the application of food science to the selection, preservation, processing, packaging, distribution and use of safe, wholesome and nutritious food. The food processing industry covers a range of food products.

The Course is organized as follows:

No	Blocks	Units
1.	Food Technology	1. Food Industry in India
2.	Processing Management	1. Basics of Food Processing 2. Food Safety and Costs Analysis 3. Case studies on project formulation in various types of food industries

VI. Theory

Block 1: Food Technology

Unit 1: Food Industry in India: Present status of food industry in India; Organization in food industry; Introduction to operations of food industry; Deteriorative factors and hazards during processing, storage, handling and distribution.

Block 2: Processing Management

Unit 2: Basics of Food Processing: Basic principles of food processing and food preservation through technology interventions; Application of energy, radiations, chemicals and other agents for food preservation; aseptic modes of processing-freezing, quick, cryogenic, high pressure, membrane technology; Packaging of foods, labelling techniques, advanced technologies for packaging.

Unit 3: Food Safety and Costs Analysis: Analysis of costs; risk management; Laws and regulations w.r.t to food industry including production, processing and marketing; Food Safety and Quality Standards-AGMARK, BIS/ISO, FPO, FSSAI, TQM, HACCP etc.

Unit 4: Case studies on project formulation in various types of foodindustries: Discussion sessions and analysis of Case studies related to dairy, cereal milling, sugarcane production; baking/confectionary, vegetable storage, handling, egg processing, fish and meat products; Cases related HACCP.

VII. Learning outcome

After completion of this course, the students are expected to be able to acquaint the students with different food processing techniques and their management.

VIII. Suggested Reading

- Acharya SS and Aggarwal NL. 2004. *Agricultural Marketing in India*. Oxford & IBH.
- Early R. 1995. *Guide to Quality Management Systems for Food Industries*. Springer
- Jelen P. 1985. *Introduction to Food Processing*. Reston Publishing.
- Potly VH and Mulky MJ. 1993. *Food Processing*. Oxford & IBH
- Fellows PJ. 2016. *Food Processing Technology Principles and Practice,* Woodhead Publishing, 4th Edition
- Potter NN. 2018. *Food science*. McGraw-Hill Education, 6th Edition
- Singh RP, Heldman DR. 2013. *Introduction to Food Engineering.* Elsevier Inc., 5th Edition
- Smith JS, Hui YH. 2013. *Food Processing: Principles and Applications*, Wiley

I. Course Title : Rural Marketing

II. Course Code : ABM 511

III. Credit Hours : 3+0

IV. Aim of the course

To explore the possibilities and potential of the rural market. It aims at critically analysing the market opportunities, consumer trends and patterns and development of better marketing strategies for the rural areas.

The Course is organized as follows:

No	Blocks	Units
1	Rural MarketingEnvironment	1. Rural Market Concept & Scope 2. Environmental factors 3. Rural finance 4. Rural consumer's behavior
2	Rural Marketing Strategy	1. Rural Product strategy 2. Pricing for rural markets 3. Promotion and communication strategy

V. Theory

Block 1: Rural Marketing Environment

Unit 1: Rural Market Concept & Scope: Concept, Definition and Scope of rural marketing, nature and characteristics of rural markets, potential of rural markets in India, rural V/S urban market.

Unit 2: Environmental factors: Socio-cultural, economic, demographic, technological and other environmental factors affecting rural marketing.

Unit 3: Rural finance: Concept, demand, banking model; Finance Schemes of NABARD, Other Schemes of State Govt, Central Govt.

Unit 4: Rural consumer's behavior: Behavior of rural consumers and farmers; buyer characteristics and buying behavior; customer relationship management, rural market research.

Block 2: Rural Marketing Strategy

Unit 1: Rural Product strategy: Marketing of consumer durable and non-durable goods and services in the rural markets with special reference toproduct planning; marketing mix, product mix.

Unit 2: Pricing for rural markets: Pricing policy and pricing strategy, distribution strategy, Rural retailing and modern store formats in rural areas.

Unit 3: Promotion and communication strategy: Media Planning, Distribution channels, personal selling strategies in rural markets, innovations in rural marketing

Teaching methods/activities

- Lectures
- Discussion
- Case Studies
- Student-led presentations

V. Learning outcome

After completion of this course, the students are expected to be able to develop understanding regarding issues in rural markets like marketing environment, consumer behaviour, distribution channels, marketing strategies, etc.

VI. Suggested Reading

- Krishnamacharyulu and Ramakrishnan. 2010. *Rural Marketing: Text and Cases*: Pearson Education. 2nd edition
- Singh S. 2004. *Rural Marketing: Focus on Agricultural Inputs,* Vikas Publishing
- Kashyap P. 2011. *Rural Marketing*. Pearson Education
- Kumar D and Gupta P. 2017. *Rural Marketing: Challenges andOpportunities*. Sage Publications.

I. Course Title : Fertilizer Technology and Management

II. Course Code : ABM 512

III. Credit Hours : 3+0

IV. Why this course?

Provide exposure to most recent Nitrogenous and Complex fertilizer production technologies. Improve participants' technical knowledge over a varied range of fertilizer production techniques

V. Aim of the course

Enhance the participants' analytical and trouble-shooting skills by generating awareness to identify and resolve operational inefficiencies, if any, of their facilities. The Course is organized as follows:

No	Blocks	Units
1	Fertilizer Production	1. Fertilizer development 2. Raw material 3. Production efficiency
2	Testing and Field Trials	1. Testing 2. Field trials

VI. Theory

Block 1: Fertilizer Production

Unit 1: Fertilizer development: Concept, scope, need, resource availability; import and export avenues for fertilizer; types of fertilizers, grading and chemical constituents, role of fertilizers in agricultural production, production and consumption of fertilizer in India.

Unit 2: Raw material Supply; Principles of manufacturing-potassic fertilizers, secondary and micro-nutrient formulations

Unit 3: Production efficiency: Production efficiency and capacity utilization; quality control and legal aspects fertilizer control order

Block 2: Testing and Field Trials

Unit 1: Testing facilities; constraints in fertilizer use; assessment of demand and supply of different fertilizers, fertilizer distribution, fertilizer storage.

Unit 2: Field trialsand demonstrations; environmental pollution due to fertilizers

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

Provide a platform to exchange ideas on a varied range of production topics, opportunity for active interaction with leading technology experts and to acquaint the students in latest advances in fertilizer technologymanagement.

IX. Suggested Reading

- Brady NC & Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- *Fertilizer Control Order* (different years). Fertilizer Association of India, New Delhi.
- *Fertilizer Statistics* (different years). Fertilizer Association of India, New Delhi
- *Indian Journal of Fertilizers* (different years). Fertilizer Association of India, New Delhi.
- San Chilli V. 1960. *Chemistry and Technology of Fertilizers*. American Chemical Soc. Monograph Series. Reinhold Publ. Corp.
- Tisdale SL, Nelson WL, Beaton JD & Havlin JL. 2002. *Soil Fertility and Fertilizers*. 5th Ed. Prentice Hall

I. Course Title : Management of Agro Chemical Industry

II. Course Code : ABM 513

III. Credit Hours : 3+0

IV. Why this course?

The agrochemicals (pesticides, hydrogels, plant growth regulators etc.) have played a pivotal role in the past in increasing agricultural productivity and production, and in protecting and preserving the human and animal food, feed, health and the belongings.

V. Aim of the course

Plant protection chemicals have and will continue to play a crucial role in meeting the food, feed and fiber needs of the mankind.

The Course is organized as follows:

No	Blocks	Units
1.	Agro Chemicals	1. Agro Chemicals 2. Insecticides 3. Fungicides
2.	Insecticide Act and Plant Protection	1. Insecticide Act. 2. Plant Protection

VI. Theory

Block 1: Agro Chemicals

Unit 1: Introduction: Agro-chemicals: Definition and classification; Basic knowledge of agro- chemicals; role andstatus of agro-chemical industry in India; Pesticides – Classification and Introduction, knowledge of different pesticides.

Unit 2: Insecticides: Insecticides – Definition and classification based on (a)Mode of Entry (b) Mode of Action and(c) ChemicalStructure with example; Insecticidal formulation; preliminary knowledge of mode of action of insecticides; knowledge of plant protection equipments.

Unit 3: Fungicides: Fungicides – Classification and preliminary knowledge of commonly used fungicides; Biomagnifications ofpesticides and pesticidal pollution.

Block 2: Insecticide Act and Plant Protection

Unit 1: Insecticide Act: Introductory knowledge about development of agro-chemicals; Insecticidal poisoning, symptoms and treatment; Main features of Insecticide Act.

Unit 2: Plant Protection: Directorate of Plant Protection, Quarantine and Storage– A brief account of its organizational set up and functions; IPM Concept – Bio-pesticides – Plant products.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To familiarize the students with the agrochemicals, their structure, classification and development and management of agro-chemical industry.

IX. Suggested Reading

- Dhaliwal GS, Singh R and Chhillar BS. 2014. *Essentials of Agricultural Entomology*. Kalyani Publishers.
- Hayes WT and Laws ET. 1991. *Hand Book of Pesticides*. Academic Press.
- Matsumura F. 1985. *Toxicology of Insecticides*. 2nd Ed. Plenum Publ.
- Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.

I. Course Title : Seed Production Technology Management

II. Course code : ABM 514

III. Credit Hours : 3+0

IV. Aim of the course

The course covers a wide range of seed science and technology issues related to production of high quality seeds, processing, testing, certification, quality control, seed policies and regulations, variety release and registration, seed quality management in *seed* multiplication systems, seed storage, marketing.

The Course is organized as follows:

No	Blocks	Units
1.	Seed Technology	1. Seed Technology
2.	Seed Management Programmes	1. Development and Management of Seed

No	Blocks	Units
		2. Maintenance of genetic purity 3. Management of seed processing plant 4. Seed Marketing

V. Theory

Block 1: Seed Technology

Unit 1: Seed Technology: Role of Seed Technology, its Course Objective and goal, Seed Industry in India, National Seed Corporation – Tarai Seed Development, Corporation, State Seed Corporations, National Seed Project and State Farms and their role.

Block 2: Seed Management

Unit 1: Development and Management of Seed Programmes: Seed Village Concept, Basic Strategy of Seed Production and Planning and Organization of Seed Programme; Types of Seed Programme–Nucleus seed, Breeders seed, Foundation seed and Certified seed etc.

Unit 2: Maintenance of genetic purity: Minimum seed certification standard and Management of breeders & Nucleus seed; Management of seed testing laboratory and research and development.

Unit 3: Management of seed processing plant seed storage management; seed packaging and handling.

Unit 4: Seed Marketing: GM Crop seed, IPR, PBR, Patents and related issues and their impact on developing countries; Statutory intervention in the seed industry; Seed legislation and seed law enforcement, Seed act; Orientation and visit to seed production farms, seed processing Units, NSC, RSSC, RSSCA and seed testing laboratories.

VI. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VII. Learning outcome

To apprise students regarding principles and efficient management of seed production technology.

VIII. Suggested Reading

- Agrawal RL. 2017. *Seed Technology*. Oxford & IBH.
- Desai BB, Katecha PM and Salunkhe DK. 2009. *Seed Handbook: Biology, Production, Processing and Storage*. Marcel Dekker.
- Kelly A. 1988. *Seed Production of Agricultural Crops*. Longman.
- McDonald MB Jr. and Copeland LO. 2012. *Seed Production: Principles and Practices*. Chapman & Hall.

I. Course Title : Technology Management for Livestock Products

II. Course code : ABM 515

III. Credit Hours : 3+0

IV. Why this course?

Students may study two major topics include meat technology and dairy technology.

They may also do research activities on product development, development of functional meat, an extension of shelf life, and development of milk products.

V. Aim of the course

The main aim of this course is to disseminating knowledge about hygienic milk production, hygienic slaughter, utilization of slaughterhouse by-products, preparation of value-added meat products, preparing of value-added indigenous as well as milk products, and dressing of food animals.

The Course is organized as follows:

No	Blocks	Units
1.	Livestock product & Technology	1. Status of livestock product and technology 2. Manufacturing technologies
2.	TQM and Marketing of Livestock Products	1. TQM in processing 2. Marketing livestock products

VI. Theory

Block 1: Livestock Product and Technology

Unit 1: Present status of livestock products industry in India: Dairy, meat, skin and hides, wool, etc; SWOT analysis of livestock product industry, importance of value addition of livestock products, Concept of organic milk and meat. New techniques of biotechnology for improving food value.

Unit 2: Manufacturing technologies: Dairy-Manufacturing technologies of various dairy products and byproduct utilization. Meat- Manufacturingtechnologies of meat and its products, industrial processing and utilization of wool and animal by-products, valueadded egg product development.

Unit 3: Milk and meat processing plant: Layout and designing of milk and meat processing plant, abattoir design, sanitation and basic slaughterhouse practices, Plant Management- Production, planning and control, packaging, preservation and storage system for livestock products; transportation system for domestic markets and international markets.

Block 2: TQM and Marketing of Livestock Products

Unit1: Total quality management in processingTotal quality management in processing of milk and its byproduct, meat and byproduct, value added eggduct and wool, Quality control measures during storage transit; extent of losses during storage and transport, management measures to minimize the loss.

Unit 2: Marketing livestock products

Milk, meat, wool, fish etc and its byproduct, Marketing and distribution system of animal products; National and international specifications and quality standards for various products; environmental and legal issues involved.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To impart knowledge about management of livestock products, product development, quality control, preservation and marketing strategies for livestock products.

IX. Suggested Reading

- Mandal PK and Biswas AK. 2014. *Animal Products Technology,* Studium Press India Pvt. Ltd.; 1st Edition
- Bishwas AK and Mandal PK. 2014. *Textbook of Poultry, Egg and FishProcessing Technology,* Studium Press (India) Pvt. Ltd.

I. Course Title : Fruit Production and Post-Harvest Management

II. Course Code : ABM 516

III. Credit Hours : 3+0

IV. Why this course?

Postharvest management of fruits and vegetable: A potential for reducing a minimum postharvest losses as well as can potentially reduce production cost .

V. Aim of the course

A dual purpose of preventing losses that occur due to harvest losses of fruits and vegetables vary from 25% to 40%, depending on the kind of produce and the pre and post-harvest practices they are put through. The Course is organized as follows:

No	Blocks	Units
1.	Fruit Production	1. Introduction 2. Management of horticultural crops
2.	Post-Harvest Management	1. Post harvest management in horticulture-procurement 2. Post harvest management in horticulture process 3. Marketing of fruits

VI. Theory

Block 1: Fruit Production

Unit 1: Introduction: Global and National Status of Horticultural production in India and emerging scenario

Unit 2: Management of horticultural crops: Establishing an orchard, basic cultural practices, regulation of flowering, fruiting and thinning, protection against insect-pest, weeds: Maturity indices, Harvesting and its relationship with quality, sorting and grading, pre-harvest crop management practices and their influence on quality during storage and marketing.

Block 2: **Post-Harvest Management**

Unit 1: Post-harvest management in horticulture-procurement: Procurement management, important factors for marketing, standardization and quality control, packaging. Physiology of ripening and senescence. Storage system: on-farm storage-evaporatively cooled stores, ventilated storage, pit storage etc. Refrigerated storage refrigeration cycle, controlled/modified atmosphere, hypobaric storage.

Unit 2: Post harvest management in horticulture process: Application of growth regulators for quality assurance, post-harvest treatments: pre cooling, heat treatments (hot water, hot air and vapor heat), fungicides & biologically safe chemicals, irradiation, curing, pulsing *etc*. Packingline operations, packaging of horticultural produce. Transportation rail, road, sea, air. Codex norms for export ofperishables. Development of fruit-based carbonated drinks, development of dehydrated products from someimportant fruits, storage of pulp in pouches, essential oils from fruit waste, dehydrated fruits. Market structure andexport potential of fruits.

Unit 3: Marketing of fruits: Problems in marketing of fruits, and government policy; quality standards for domestic and international trade.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To impart knowledge about management of horticultural crops and post-harvest technologies

IX. Suggested Reading

- Rathore NS, Mathur GK and Chasta SS. 2013. *Post-Harvest Management and Processing of Fruits and Vegetables*, ICAR.
- Chadha KL and Pareek OP. 1993. *Advances in Horticulture*. Vols. I-IV. Malhotra Publ. House.
- Kader AA. 1992. *Post-harvest Technology of Horticultural Crops*. Univ. of California. Div. of Agri. & Natural Resources.
- Jacob JP. 2012. Handbook on Post Harvest Management of Fruits and Vegetables, ASTRAL Publishing.
- NIIR Board of Consultants & Engineers. 2016. *The Complete Technology Book on Processing, Dehydration, Canning, Preservation of Fruits & Vegetables*, NIIR PROJECT CONSULTANCY SERVICES; 3rd Revised Edition
- Thompson K. 2003. *Fruit and Vegetables: Harvesting, Handling and Storage*, Wiley-Blackwell; 2nd Edition

I. Course Title : Farm Power and Machinery Management

II. Course Code : ABM 517

III. Credit Hours : 2+0

IV. Why this course?

The role of mechanization and its relationship to productivity, employment, social and technological change; performance and *power* analysis(Various sources of *farm power*, their availability and utilization) cost analysis of mechanized agriculture.

V. Aim of the course

Agricultural machinery management is the section of farm management that deals with the optimization ofthe equipment phases of agricultural production. It is concerned with the efficient selection, operation, repair and maintenance, and replacement of machinery.

The Course is organized as follows:

No	Blocks	Units
1.	Farm Power and Machinery	1. Farm power and tractors 2. Tillage and Tillage machinery 3. Sowing, Planting and Intercultural Equipment
2.	Agricultural equipments industry and Cost analysis of operations	1. Agricultural equipments industry 2. Cost analysis of operations

VI. Theory

Block 1: Farm Power And Machinery

Unit 1: Farm power and tractors: Farm power in India - sources, IC engines – working principles, two stoke and four stoke engines, IC engine terminology, different systems of IC engine. Tractors – types and utilities.

Unit 2: Tillage and Tillage machinery: Tillage – ploughing methods – primary tillage implements – mould board, disc plough and chisel plough – secondary tillage implements –cultivators, harrows and rotovators – wetland equipment – puddlers, tramplers and cage wheels.

Unit 3: Sowing, Planting and Intercultural Equipment: Sowing methods – seed drills, seed cum fertilizer drills – Paddy transplanters – nursery requirements – implements for intercultural operations – wet land, dry land and garden land intercultural tools. Plant Protection Gadgets, Harvesting Machinery and Horticulture tools: Plant protection equipment, tools for horticultural crops.

Block 2: Agricultural Equipments Industry and Cost Analysis Of Operations

Unit 1: Agricultural equipments industry: Agricultural equipments production, marketing and constraints; establishment of agricultural engineering enterprises (agro service centers, etc.). Equipment for land development and farm machinery selection: Equipment for land development and soil conservation.

Unit 2: Cost analysis of operations: Cost analysis ofoperations using different implements, economic performance of machines, optimization of tractor implements system and transport of farm produce. Cost of operation of farm machinery – Tractor and implement selection

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To equip the students with sufficient theoretical knowledge and practical skills about farm power and tractor power, implement resources used in agriculture, their cost of operation and selection.

IX. Suggested Reading

- Senthilkumar T, Kavitha R and Duraisamy VM. 2015. *A text book of farm machinery*, Thannambikkai Publications, Coimbatore.
- Jagadishwar S. 2010. *Elements of agricultural engineering*. Standard Publishers Distributors, New Delhi.

I. Course Title : Food Retail Management

II. Course Code : ABM 518

III. Credit Hours : 2+0

IV. Why this course?

Study a short *course* in *Retail Management* to learn how to run a retail store or department efficiently and to introduce you to key issues and concepts associated with the *retail* environment. Topics covered in the *course* typically include business administration, visual merchandising, and marketing.

V. Aim of the course

Identify the most dramatic change in food retailing today; Assess the variety and Define a target market; Explain why a retailer would want to meet the needs of a Customer. Describe the steps to recruiting top talent; Identify selection and training.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction to Food market 2. Value Chain in Food Retailing
2.	Retail Marketing Strategy	1. Marketing Mix in Food Retail Management 2. Managing Retail Operations 3. Retail Sales Management

VI. Theory

Block 1: Introduction

Unit 1: Introduction to Food market: Introduction to International Food market, India's Competitive Position in World Food Trade, Foreign Investment in Global Food Industry, Retail management and Food Retailing, The Nature of Change in Retailing, Organized Retailing in India, E-tailing and Understanding food preference of Indian Consumer, Food consumption and Expenditure pattern, Demographic and Psychographic factors affecting Food Pattern of Indian Consumer.

Unit 2: Value Chain in Food Retailing: Value chain and value additions across the chain in food retail, Principal trends in food wholesaling and retailing, Competition and pricing in food retailing, various retailing formats, the changing nature of food stores, market implications of new retail developments, food service marketing.

Block 2: Retail Marketing Strategy

Unit 1: Marketing Mix in Food Retail Management: Merchandise Management, Pricing Strategies used in conventional and non-conventional food retailing, Public distribution system, Promotion mix for food retailing, Management of sales promotion and Publicity, Advertisement Strategies for food retailers & Brand Management in Retailing.

Unit 2: Managing Retail Operations: Managing Retailers' Finances, Merchandise buying and handling, Logistics, procurement of Food products and Handling Transportation of Food Products.

Unit 3: Retail Sales Management: Types of Retail Selling, Salesperson selection, Salesperson training, Evaluation and Monitoring, Customer Relationship Management, Managing Human Resources in retailing, Legal and Ethical issues in Retailing.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

It will equip the students with desired knowledge and skills for managing food retail operations.

IX. Suggested Reading

- Singh S. 2011. *Fresh food retails in India: Organisation and impacts,* Allied publishers Pvt. Ltd., New Delhi
- Mahapatra. S, *Food Retail Management*, Kalyani Publishers
- Zentes, Joachim, Morschett, Dirk, Schramm-Klein, Hanna 2017. *Strategic Retail Management: Text and International Cases,* Springer Gabler.
- Agrawal N and Smith SA. 2015. *Retail Supply chain Management: Quantitative Models and Empirical Studies,* Springer; 2nd revised edition.

I. Course Title : Management of Agricultrual Input Marketing

II. Course Code : ABM 519

III. Credit Hours : 2+0

IV. Why this course?

It will help in gaining a deeper understanding of the four P's of marketing as applied to agricultural input marketing and an exposure to social and ethical issues is oriented in the course.

V. Aim of the course

The present course aims at familiarizing the participants with various aspects of agricultural input marketing in India.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Market for agricultural inputs
2.	Marketing of Agricultural Inputs	1. Marketing of seeds 2. Marketing of fertilizers 3. Marketing of pesticides 4. Marketing of tractors

VI. Theory

Block 1: Introduction

Unit 1: Market for agricultural inputs: Nature of demand, promotional media, nature of competition, a framework for understanding the markets for inputs, agronomic potential, agro economic potential, effective demand, actual consumption.

Block 2: Marketing of Agricultural Inputs

Unit 1: Marketing of seeds: Government policy, product, trade practices in seed production, seed pricing, input costs, distribution system, management of seed distribution. proper storage of seeds, promotion, problems faced by seed industry, strategy for a seed enterprise, source of seeds, terms of transaction for seed procurements.

Unit 2: Marketing of fertilizers: Nature of Indian fertilizer market, product, fertilizer distribution, marketing cost and margins, credit, dealer selection and management, fertilizer promotion and extension, promotional program, advertising in fertilizers, emerging marketing mix in fertilizer, extension strategy for the future, marketing of biofertilizers, strategies for fertilizer marketing.

Unit 3: Marketing of pesticides: Market profile, structure of industry, farmer behaviour, problems of farmers in pesticide purchase and usage, marketing mix, bio pesticides market development and promotion activities, problems in marketing of bio pesticides. Integrated pest management.

Unit 4: Marketing of tractors: Segments in tractor market, market share, nature of demand, buyer behaviour, role of distribution, promotion, MNC's. Marketing of credit-Nature of market, market segment, market players, marketing mix, marketing options. Strategies for input marketing-Client and location specific promotion, joint promotion, interdependence of input markets, management of demands, developmental marketing, usp, extension services, ethics in business, sustainability.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To enhance the understanding and analytical capabilities with respect to products, market environment, and operational issues in marketing of agricultural inputs.

IX. Suggested Reading

- Mahapatra. S. *Management of Agricultural Inputs*, NIPA Publishers
- Seetharaman SP.: *Agricultural Input Marketing,* Oxford & IBH Pub. Co.
- Krishnamacharyulu CSG. : *Rural Marketing: Text and Cases*, Pearson Education India Venugopal P. 2014. *Agri-input Marketing in India,* SAGE Publication; 1st Edition.

I. Course Title : Feed Business Management

II. Course Code : ABM 520

III. Credit Hours : 2+0

IV. Why this course?

It will help in gaining a deeper understanding of the production, processing and marketing of cattle feed, poultry feed and fish feed.

V. Aim of the course

The present course aims at familiarizing the participants with various aspects feed for livestock and poultry.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Feed resources 2. Nutrients requirements of livestock and poultry
2.	Feed Preparation and Distribution	1. Feed preparation 2. Importance of mineral mixture 3. Feed Distribution

VI. Theory

Block 1: Introduction

Unit 1: Feed resources: Gap between demand and availability of nutrients; status of feed industry in India and world, constraints in the development of Indian feed industry.

Unit 2: Nutrients requirements of livestock and poultry: Knowledge about the quality of feed ingredients used in feed manufacturing. Procurement procedure of feed ingredients, scientific storage of feeds and feed ingredients. BIS, CLAFMA and all other commercial standards of all class of livestock and poultry feeds.

Block 2: Feed Preparation and Distribution

Unit 1: Feed preparation: Layout and design of feed plants, feed plant management; Basic principles of processing of feeds, Feed preparation for cattle and poultry and as specialty feeds for aqua and pet animals.

Unit 2: Importance of mineral mixture: Feed additives, supplements and pass feed, to know the new technology regarding improving the feeding value of poor quality roughages. To acquaint the concept of silage technology, complete feed block technology, hydroponics technology and UMMB technology.

Unit 3: Feed Distribution: Distribution channels, regulations relating to manufacture and sale of feed stuffs.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To acquaint the students with the role and importance of feed industry and the production of feed for livestock and poultry.

IX. Suggested Reading

- Morrison FB. 1961. *Feeds and Feeding*, Abridged, Morrison Publishing; 9th edition John.
- Moran. 2005. Tropical Dairy Farming: Feeding Management for Small Holder Dairy Farmers in the Humid Tropics, Csiro Publishing.
- Moran J and McDonald S. 2010. *Feedpads for Grazing Dairy Cows,* Csiro Publishing.
- Kellems RO and Church DC. 2009. *Livestock Feeds and Feeding*, Pearson; 6th Edition

I. Course Title : Managmement of Veterinary Hospitals

II. Course Code : ABM 521

III. Credit Hours : 2+0

IV. Aim of the course

It will help in gaining a deeper understanding of the Veterinary Science is the science of *treating* and curing the diverse types of Animals.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Feed resources 2. Nutrients requirements of livestock and poultry
2.	Feed Preparation and Distribution	1. Feed preparation 2. Importance of mineral mixture 3. Feed Distribution

V. Theory

Block 1: Veterinary Hospital Administration

Unit 1: Needs, aims and objectives: Objectives of Veterinary hospitals; the existing and simulated situations under which veterinary hospitals work or are to work.
Unit 2: Designing and planning an ideal hospital: Optimizing the use of resources - human, space, equipment, drugs, time, capital, etc.; Materials management and problems Normal purchase procedure. Receipt; storage and distribution of materials Cost reduction & scientific inventory control. Information system and materials management performance. Equipment maintenance, condemnation & disposal.
Unit 3: Authority, responsibility: Accountability of management for optimizing the use of skill, developing and upgrading skills and technology; efficient system of record keeping and accounting; Concept of quality & Total quality management (TQM) Introduction to Veterinary audit, Statistical quality control (SQC), Quality control Circle (QCC).

Block 2: Information System & Quality Control

Unit 1: Hospital information system: Hospital information system as an aid to efficient controlling and monitoring; need for financial resources - investment and working capital; Records: Types & Methodology, Reports and Reporting system. Contemporary and need-based methods of accounting; General consideration. Need based information system. Applicability in surveillance & monitoring; planning & policy making; cost control.
Unit 2: Quality control system: Economic functions and quality control system; Animal health Economics: An introduction Need for financial resources (type and need). Investment planning and working capital; Budgeting and cost cutting (cost control). legal aspects in the functioning of the hospital.

VI. Learning outcome

The objective of this course is to acquaint the students about the designing, planning, organizing, and controlling the veterinary hospitals for optimizing the use of space, capital, skill and other resources.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

I. Course Title : Poutlry and Hatchery Management
II. Course Code : ABM 522
III. Credit Hours : 2+0

IV. Why this course?

This course introduces about updated production standards achievable under field conditions and financial viability of poultry operations. This specialized course is designed to train persons in Incubation and Hatchery Management and is meant for those engaged in or scheduled to take up Hatchery operations.

V. Aim of the course

To give the opportunity for trainees to learn about raising chickens for their meat and eggs in order to manage a small-scale, commercial poultry enterprise that will be profitable

The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Poultry and hatchery Business 2. Poultry and hatchery unit
2	Hatcheries and Risk Management	1. Incubation and hatching 2. Franchise hatcheries management 3. Personal management and insurance

VI. Theory

Block 1: Introduction to Poultry and Hatchery Industry

Unit 1: Poultry and hatchery Business: Poultry and hatchery industry; Present scenario of Poultry industry, Integration in poultry farming, Scope and future perspective, role of management in poultry industry.

Unit 2: Poultry and hatchery unit: Planning and establishing a poultry and hatchery unit- location, size and construction; farm and hatchery equipments and physical facilities; organizing and managing a poultry farm and hatchery.

Block 2: Hatcheries and Risk Management

Unit 1: Incubation and hatching Production of quality chicks and eggs; factors affecting hatchability; bio-securityand hatchery sanitation; handling of hatching eggs; maintaining chick quality-chick grading, sexing, packing, dispatch, transportation and chick delivery.

Unit 2: Franchise hatcheries management: Custom hatching; brooding; growing and laying management; crisis management; industrial breeding, feeding, housing and disease management; waste management; Record management; cost accounting and budgetary control.

Unit 3: Personal management and insurance: Labour relations including wages and salaries, job evaluation and employee appraisal; marketing management direct sale and sale through franchisees/ agents, advertisement, sale and after sale services, other innovative sales strategies.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

The course provides an insight into the importance of management in poultry industry, managing a poultry and hatchery enterprise, planning production of poultry products, financial, personnel and marketing management.

IX. Suggested Reading

- Handbook of Poultry Science.
- Rathinam GK. 2015. *Manual of Hatchery Management: For Poultry Professionals* Hardcover.

I. Course Title : Management of Floriculture and Landscaping

II. Course Code : ABM 523

III. Credit Hours : 2+0

IV. Why this course?

It deals with the cultivation of flowers and ornamental crops from the time of planting to the time of harvesting. It also includes production of planting materials through seeds, cuttings, budding, grafting, etc, up to the marketing of the flower and flower produce.

V. Aim of the course

The objective of this course is to expose the students with floriculture and landscaping technologies and their Agri-business implications including international trade.

The Course is organized as follows:

No	Blocks	Units
1.	Management of Floriculture	1. Introduction 2. Indoor and ornamental plants
2.	Landscaping and Trading	1. Introduction 2. Landscape gardening 3. Value-addition in floriculture

VI. Theory

Block 1: Management Offloriculture

Unit 1: Introduction: Introduction, importance and scope of floriculture industry and landscaping; Recent advances in floriculture industry.

Unit 2: Indoor and ornamental plants: Raising of foliage plants in pots, production technology of ornamental plants, commercial cultivation of flower crops (rose, jasmine gladiolus, tuberose, marigold, aster, carnation, gerbera, cilium chrysanthemum; special techniques for forcing of flowers for export.

Block 2: Landscaping and Trading

Unit 1: Introduction: Drying and dehydration of flowers; bonsai; scope of landscaping, response of flowering plants to environmental stresses;

Unit 2: Landscape gardening: Styles of gardening; modern and traditional garden planning; Socio-aesthetic planning; use of computers in designing gardens; planning towns

Unit 3: Value Addition in floriculture: Extraction, purification and storage of essential oils and perfumes; post-harvest storage changes; packing techniques of produce harvesting of flowers for export and home use, Export-Import trade in flowers and their specifications along major trading countries.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

Students are suitable for it working independently and apply the latest trends to their work. They should be able to understand about floriculture and landscaping.

IX. Suggested Reading

- Banker N. 2011. *Landscape gardening*, IBDC publishers, Lucknow
- Misra RL and Misra S. 2012. *Landscape gardening*, Westville Publishing House, New Delhi
- Chadha KL and Choudhary B. 2006, *Ornamental Horticulture in India*. ICAR. New Delhi
- Grindal EW. *Every Day Gardening in India*. DB Tarporevala Sons.
- Randhawa GS and Mukhopadhyay A. 1998, *Floriculture in India*. Allied Publ., New Delhi

I. Course Title : Risk Management in Agri Business

II. Course Code : ABM 524

III. Credit Hours : 2+0

IV. Why this course?

Risk and uncertainities is involved in food and Agribusiness industries. Government to formulate policy that will encourage investors adopt the highlighted risk keeping in view priority of food security for rising population. The focus is to foster profitability in agri-allied sector.

V. Aim of the course

Identification, mitigation and management of risk is unique to agriculture-production, markets, finance, Institutions and HR. Policy implications at local, regional, national as well as international level. Data analysis and research findings to help in decision making at firm and industry levels using history to guide future events/projection, Degree of risk varies in agri-business compared to other sectors.

The Course is organized as follows:

No	Blocks	Units
1.	Risk Management process	1. Financial intermediation 2. Strategic Issues in Bank Marketing 3. Credit policy in banks
2.	Introduction to banking Operations and Risk Management	1. Banking operations 2. Definition of Risk and risk management techniques

VI. Theory

Block 1: Risk Management Process

Unit 1. Financial Intermediation, Indian Financial system, Origin and Growth of Banking. RBI and its functions. Principles of Banking, Banking Law and Practice. Nationalization of Banks in India, Deposit Products, Lending Activities, Retail Banking, Wealth Management, Financing SMEs, Corporate Banking, Forex Management, Fee-Based & Subsidiary Services, Plastic Money, Role of Central Banks, Emerging Trends in Banking, Fundamentals of International Banking.

Unit 2: Strategic Issues in Bank Marketing, Positioning Bank Services in the Market, New Product Development, Pricing and Launching, New Distribution Channels for Bank Marketing, Communicating and Promoting Bank Services, Improving Quality and Productivity, Customer Relationship Management in Banks, Globalizing Bank Services, Opportunities and Challenges in Bank Marketing.

Unit 3: Credit Policy in Banks, Principles of Credit Management, Objectives of Credit Management, Credit Disbursal and Monitoring, Credit Deployment and

Types of Borrowers, Follow up and Recovery Management, Treasury Operations, Introduction to Risk Management in Banks, Rural Banking in India, Security Considerations, Control System in Banks, Corporate Governance in Banks, Annual Reports and Statutory Audit.

Block 2: Introduction to Banking Operations and Risk Management

Unit 1: Introduction to Banking Operations, Front Office and Back Office Operations, Operational Controls, Demand Forecasting and Resource Allocation, Policy Framing – Deposits, Advances and Investments, Services Design and Delivery Strategies in Banks, Service Quality Metrics, Work Measurement and Quality Assurance, Payment and Settlement Systems, RTGS and Clearing House, Cash Management Services, Facilities Planning, ERP in Banks, BPR in Banks, IT Enabled Supply Chain Management, Disaster and Recovery Management.

Unit 2. Introduction to Risk, Risk Management Essentials, Measurement of Risk, Loss Exposure, Risk Management – Non-insurance Techniques, Introduction to Insurance, Principles of Insurance, Insurance Industry, Insurance Market, Insurance as Risk Management Techniques, Selection and Implementation of Risk Management Techniques.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

Developing an understanding of the different types of risk in general to agriculture sector and with special reference to agriculture business.

IX. Suggested Reading

- Sethi J and Bhatia N. 2012. *Elements of Banking and Insurance*. PHI Learning
- Jian W and Rehman A. 2016. *Risk Management in Agriculture: Theories and Methods.* Science Publishing group
- Hardaker JB, Huirne RBM, Anderson JR and Lien G. 2004. *Coping With Risk in Agriculture,* CABI Publishing, 2nd Edition
- Rose PS and Hudgins SC. 2006. *Bank Management & Financial Services.* Mcgraw-Hill College; 7th edition

I. Course Title : Management of Agribusiness Cooperatives

II. Course Code : ABM 525

III. Credit Hours : 2+0

IV. Why this course?

Proper management enables **c**ooperatives to offer high quality, efficient and effective services to their members. Moreover, well managed agricultural cooperatives can also contribute to wider development issues such as food security, sustainable use of natural resources and inclusive employment creation.

V. Aim of the course

These cooperatives were usually initiated by small scale farmers, as a response to their weak position in the market. By joining forces they could improve this position and obtain better prices and services for the purchase of inputs and the marketing of produce.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Cooperative administration 2. Cooperative management
2.	Cooperative Movement and Management	1. Cooperative Movement 2. Human resource management 3. Overview of agribusiness cooperative

VI. Theory

Block 1: Introduction

Unit 1: Cooperative administration: Global perspective, ecology of cooperative administration, cooperative sector and economic development.

Unit 2: Cooperative management: Nature, functions and purpose of cooperatives –procurement, storage, processing, marketing, process of cooperative formation, role of leadership in cooperative management.

Block 2: Cooperative Movement and Management

Unit 1: Cooperative Movement: The state and cooperative movement, effects of cooperative law in management, long range planning for cooperative expansion, policy making.

Unit 2: Human resource management: Placement and role of board of directors in cooperative management.

Unit 3: Overview of agribusiness cooperative: Credit cooperatives, cooperative marketing, dairy cooperative; financing agribusiness cooperative.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To provide the students an understanding about the agribusiness cooperative organizations and their management.

IX. Suggested Reading

- Kamat GS. 2011. *New Dimensions of Cooperative Management*. Himalaya Publ. House.
- Ansari AA. 1990. *Cooperative Management Patterns*. Anmol Publ.
- Ravichandran and Nakkiran. 2009. *Cooperation* (*Theory & Practice*) Neha Publishers & Distributors;
- Sah AK. 1984. *Professional Management for the Cooperatives*. Vikas Publ. House.
- Anwar SA. *HRM Practise in Cooperative Sector*. Idea Publishing.

I. Course Title : Business Analytics for Agriculture

II. Course Code : ABM 526

III. Credit Hours : 1+1

IV. Why this course?

Analytics can enble farmers to make data-based decisions like which crops to plant for their next harvest. Reality as actionable insights to make decisions on data and information to improve agronomic opportunities, such as timing of applications, product decisions, amounts of products, and profitability of decision making.

V. Aim of the course

To make the students understand the concepts of data science tools and techniques and develop the skills for using it strategically and for the developing of the agri business sector.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction 2. Fundamentals of Research
2.	Machine and Deep Learning	1. Supervised machine learning-1 2. Supervised machine learning-2 3. Deep learning

VI. Theory

Block 1: Introduction

Unit 1: Introduction to data science, evolution of data science, work profile of a data scientist, career in data science, nature of data science, typical working day of a data scientist, importance of data science in agribusiness; defining algorithm, big data, business analytics, statistical learning, defining machine learning, defining artificial intelligence, data mining; difference between analysis and analytics, business intelligence and business analytics, typical process of business analytics cycle.

Unit 2: Fundamental of Research

Fundamentals of R and RStudio, fundamentals of packages of RStudio, data manipulations, data transformations, normalization, standardization, missing values imputation, dummy variables, data visualization (2D and 3D), basic architecture of machine learning analytical cycle, descriptive analytics-case study covering data manipulation, measures of central tendency, measures of dispersion, measures of distribution, measures of associations, t-test, f-test, ANOVA, Chi-square test, basic statistical modeling framework.

Block 2: Machine and Deep Learning

Unit 1: Supervised machine learning: Basic framework, regression models and classification models. Linear regression, nonlinear regression, multiple regression, polynomial regression, lasso regression, ridge regression, stepwise regression, quantile regression, logistic regression.

Unit 2: Supervised machine learning: Linear discriminant analysis, principal component analysis, factor analysis, support vector machines, naïve Bayes, nearest neighbors, decision trees, random forest, ensemble methods, *k*-fold cross validation, X gradient boosting. Unsupervised machine learning—basic framework, concept of clustering, k-means, c-means, hierarchical clustering, hidden markov models, forecasting models (AR, MA, ARMA and ARIMA).

Unit 3: Deep learning: Basic framework of neural nets, types of neural nets, computer vision, object detection and localization, gradient descent optimization for loss function, regularization L1 and L2, feed forward neural nets, back propagation, recurrent neural nets, convolutional neural nets, reinforcement neural net, concurrent net, introduction to IoT. All the illustrations used in the syllabus of Data Science in Agribusiness will be primarily from agribusiness domains and RStudio will be used for practical purposes.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To equip students of agribusiness with knowledge, skills and attitude for using data science tools and techniques so that agribusiness get competent professionals who can strategically and successfully implement data science applications.

IX. Suggested Reading

- *Deep Learning with R*. MEAP Edition, Manning Early Access Program. Version 1, © 2017, Manning Publication.
- James RG, Witten D, Hastie T and Tibshirani R. 2017. *An Introduction to Statistical Learning with Application*. Springer Publication
- Millstein F. 2018. *Machine Learning With Tensorflow: A Deeper Look At Machine Learning With Tensor Flow* Frank Millstein
- Stanton J. 2012. *Introduction to Data Science*. Version 3, SAGE Publications, Inc.

I. Course Title : Dairy Business Management

II. Course Code : ABM 527

III. Credit Hours : 1+0

IV. Why this course?

The main objective of dairy management course is to provide basic input to students about production, planning and management of dairy farms, entrepreneurship development in milk preservation, entrepreneurship development in dairy processing and management of dairy farm, co-operative and industry.

V. Aim of the course

To emphasize on the application of Principles of Management in dairy business with special emphasis on co-operative dairy units. The emphasis shall be on main functional areas like Finance, Marketing, Human Resources, Production and Information Technology.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction to commodity derivatives 2. Dairy Plant Management System
2.	Dairy Business Strategy:	1. Marketing Management, Supply Chain and International Trade in Dairy sector 2. Strategic, HR Management and Entrepreneurship in Dairy Sector 3. Financial Management and Financial Analysis in dairy sector

VI. Theory

Block 1: Introduction

Unit 1: Dairy Development in India: Dairy organizations: functioning, Challenges and Opportunities, Anand pattern dairy Cooperatives: features and impact; Public sector dairy schemes, Dairy Development schemes, Dairy problems and policies, National Dairy Plan-I, Rise of Producer Companies. Policy Frameworks in context to dairying.

Unit 2: Dairy Plant Management System: Production Planning and control in dairy plants, milk procurement from the rural milk producer, milk processing and products manufacturing. Pricing and marketing of milk and milk products. Survey on milk production potential and marketed surplus of milk for setting up of milk plants, energy utilization, Conventional and nonconventional sources of energy used in dairy sector. Concept of Quality; TQM concept and Kaizen in Dairy Industry, new concepts in quality assurance (HACCP; ISO certification); patent laws, pollution control laws in relation to dairy plants. Guidelines for obtaining ISO/HACCP certification for dairy plants. SQC in dairy operations.

Block 2: Dairy Business Strategy:

Unit 1: Marketing Management, Supply Chain and International Trade in Dairy sector: Marketing- mix in relation to dairy sector, marketing environment,. Marketing Opportunities Analysis in Milk and Milk Products: Demand status of Milk and milk products in the country, growth rates, Marketing research and marketing information systems; Market measurement present and future demand; Market forecasting. Market segmentation, Product-mix; Promotion mix decisions. Advertising; Sales Promotion. Food and Dairy Products Marketing, Consumer Buying Behaviour; New product development processPrice determination and pricing policyInternational Marketing Marketing; Composition & direction of Indian exportsExports- Direct exports, indirect exports; WTO and its Implications; SPS/TBT; Supply chain Management in Dairy sectorLogistics Management: Primary and Secondary Markets; Distribution channels; chilling points

Unit 2: Strategic, HR Management and Entrepreneurship in Dairy Sector: PESTLE analysis, BCG matrix, Strategic Management in dairy industry, Governance Structure in Dairy Sector, Management control System. Organisational Performance parameters – Quantitative and Financial, Use of Balanced Score card and other strategy control tools. HR management practices in dairy sector, Promotions, transfers employee remuneration and other HR benefits and problems. Motivation, turnover, employee capacity building, Training and orientation etc. social and business economics; industrial relations and human values; labour laws; trade unionism Business Plan Preparation; TIDP plant setting; Compliances Systems in Dairy Industry

Unit 3: Financial Management and Financial Analysis in dairy sector: Nature and uses of financial analysis, Liquidity ratios, Leverage ratios, Activity ratios, Profitability ratios, Utility of Ratio analysis. Sources of long term capital in dairy Industry: Grants from NDDB, Grants from NABARD, Government and Other Schemes, cost of debt, debentures, preference share capital, equity share capital & retained earnings, overall cost of capital. Capital budgeting in dairy Industry. Various techniques: NPV, IRR, etc. Financial Planning and control in dairy Industry: Budgeting process, Problems and practices in Budgeting and evaluation. Cost Volume

– Profit analysis and operating leverage, Break-even analysis, Profit analysis and operating analysis, Utility of CVP analysis. Costing in Dairy sector: Costing Techniques and Costing of various dairy products – Milk costing based on Fat and SNF, Ice cream, milk, Paneer, etc. Essentials of sound costing system. Different methods of costing, elements of cost: Labour- recording of time, idle time, methods of remunerating labour, Premium & Bonus Plans, Materials, Overheads.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

- To understand the overall scenario of dairy and develop insights in managing dairy as a entrepreneurial venture.
- To enhance the Decision making, Critical thinking and the problem solving capabilities of the students.
- To bring out the hidden potential and entrepreneurship aptitude of the students and also to encourage team building activities.

IX. Suggested Reading

- Acharya R M and Kumar P. *Dairy Production & Business Management* EIRI, Dairy Darming
- Rao Venkateswara, *Dairy Farm Busines Management*
- Singh Umashankar, *Dairy Farming*

I. Course Title : Agri Extension Management

II. Course Code : ABM 528

III. Credit Hours : 1+0

IV. Why this course?

To enhance the techno-managerial competence of extension functionaries and to acquaint the extension functionaries on the latest developments in the field of agricultural extension

V. Aim of the course

To equip the extension functionaries in latest tools and techniques for participatory decision making and to develop an insight into various extension models to enrich the agri - value chain

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Approaches of Agricultural Extension 2. Cyber Extension
2.	Implications and contemporary issues	1. Implications of WTO 2. Extension and contemporary issues

VI. Theory

Block 1: Introduction

Unit 1: Approaches of Agricultural Extension: A critical analysis of different approaches of agricultural extension. Importance and relevance of indigenous knowledge system, identification and documentation of ITK, Integration of ITK system in research formulation, Concept of Agricultural Knowledge and Information System, Training of Stakeholders of AKIS.

Unit 2: Cyber Extension: Concept of cyber extension, national and international cases of extension projects using ICT and their impact of agricultural extension, alternative methods of financing agricultural extension - Scope, limitations and experience and cases. Research -Extension -Farmer - Market linkage: Importance, Scope, Implications etc., Market – Led Extension, Farmer - Led Extension, Concept of Farm Field School, Farm School, Public - Private Partnership: Meaning, Models, Identification of various areas for partnership. Stakeholder's analysis in Extension. Main streaming gender in Extension - Issues and Prospects

Block 2: Implications and Contemporary Issues

Unit 1: Implications of WTO: OA for extension services, re-orientation of extension services for agri-business and marketing activities, GOI- NGO collaboration to improve efficiency of extension.

Unit 2: Extension and contemporary issues: Extension and issues related to rural poverty. Privatization of Extension. Intellectual Property Rights (IPRs). Extension Reforms in India –Decentralized decision making, Bottom up planning, Farming System and Situation based Extension Delivery System, Extension delivery through Commodity Interest Groups. Organization innovations in Extension - ATIC, IVLP, Kisan Call Centres.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

By the end of the course student will be able to critically analyze different Agricultural Extension approaches, understand Agricultural Knowledge Information System (AKISs) ITK, Understand Advances in Extension - Cyber extension, ICT enabled extension services; Market Led Extension, Public Private Partnership, Mainstreaming gender in extension organizational Innovations.

IX. Suggested Reading

- Bagchi J. 2007. *Agriculture and WTO Opportunity for India*.
- Sanskruti Chambers R, Pacy A and Thrupp LA. 1989. *FarmersFirst*. Intermediate Technology Publ.
- Crouch BR and Chamala S. 1981. *Extension Education and Rural Development*. Macmillan.
- John KC, Sharma DK, Rajan CS and Singh C. 1997. *Farmers Participation in Agricultural Research and Extension Systems*. MANAGE, Concept Publ. Co.
- Khan PM. 2002. *Text Book of Extension Education*. Himanshu Publ.
- Narasaiah ML. 2005. *Agricultural Development and World Trade Organization*. Discovery Publ.
- Talwar S. 2007. *WTO Intellectual Property Rights*. Serials Publ.
- Van den Ban BW and Hawkins BS. 1998. *Agricultural Extension*. S.K. Jain Publ.
- Venkaiah S. 2001. *New Dimensions of Extension Education*. Anmol Publ.

I. Course Title : Renewable Energy Sources Management

II. Course Code : ABM 529

III. Credit Hours : 1+0

IV. Why this course?

Renewable Energy Management will contribute to the promotion of renewable energy sources in countries, especially developing nations.

V. Aim of the course

The course aims to provide fundamental clarity regarding various renewable&alternative energy sources/ technologies options available today, its usage potential & related aspects like cost, impact on environment, etc.

The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Introduction 2. Commercial application
2	Implications and contemporary issues	1. Institutional Framework 2. Devices for renewable energy development

VI. Theory

Block 1: Introduction

Unit 1: Introduction: Concept on alternate and non-conventional energy sources. Biofuels, Geothermal, Ocean, Hydropower, Biogas, Solar and Wind energy.

Unit 2: Commercial application: Commercial application of renewable energy sources and its benefits. Government Policy towards promoting renewable energy.

Block 2: Institutional Framework and Types

Unit 1: Institutional Framework: MNRE, CREDA-Renewable Energy Development Authority, State level Renewable Energy Development Agency, Society of Renewable Energy.

Unit 2: Devices for renewable energy development: Biogas plant, Wind Mills, Solar Cells – Solar Pumps, Solar Dryers, Solar water heating system, etc.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To provide an insight to the meaning and concepts of Renewable energy resources development and Institutional support as well as Government policy framework.

IX. Suggested Reading

- Sorensen B. 2010. *Renewable Energy: Physics, Engineering, Environmental Impacts, Economics and Planning*, Elsevier Publishing; 4th Edition
- Armaroli N, Balzani V and Serpone N. 2013. *Powering Planet Earth–Energy Solutions for the Future*, Wiley
- Boyle G. 2012. *Renewable Energy: Power for a Sustainable Future*, Oxford; 3rd Edition
- Twidell J, Weir T. 2013. *Renewable Energy Resources,* CRC Press; 3rd Edition
- Ahmed AI. *Renewable Energy Sources* by Jain Brothers

I. Course Title : Quality Management for Agribusienss

II. Course Code : ABM 530

III. Credit Hours : 1+0

IV. Why this course?

The focus of the process is to improve the quality of organizations outputs, including goods and services, through continual improvement of internal practices

V. Aim of the course

The course will help the students to have an understanding of the quality standards in agribusiness.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Basic concepts of quality management 2. TQM
2.	Quality grades, standards and Control	1. Quality grades and standards 2. Statistical to quality control 3. Food quality standards

VI. Theory

Block 1: Introduction

Unit 1: Basic concepts of quality management: importance of quality and the role of quality assurance in agribusiness.

Unit 2: Total Quality Manangement: TQM and business strategy. Quality control process and its relevance.

Block 2: Quality Grades, Standards And Control

Unit 1: Quality grades and standards: Overview and relevance, benefits to consumers, producers and food processors, food grades and standards for various food commodities; cereals, fruits and vegetables, meats, poultry products.

Unit 2: Statistical to quality control: Statistics relevant to quality control, quality control charts used in the food industry, process control to assure food quality, food processing.

Unit 3: Food quality standards: Food quality standards and world food trade. HACCP, ISO9000, auditing and certification.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

The course will help the students to have an understanding of the quality standards in agribusiness.

IX. Suggested Reading

- Luning PA, Marcelis WJ. 2009. *Food Quality Management: Technological and Managerial Principles and Practices*. Wageningen Academic Publishers
- Dale BG. 2004. *Managing Quality*. Blackwell Resources

I. Course Title : Advertising and Brand Management

II. Course Code : ABM 531

III. Credit Hours : 1+0

IV. Why this course?

To impart basic understanding among the candidates about the advertising along with detailed aspects of brand management practices and techniques.

V. Aim of the course

It aims to ensure consistency of message and the complementary use of media. ... measurable, persuasive brand communication programs with consumers.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction to Advertising Management 2. Message Strategy 3. Consumer Promotions and Trade Promotions
2.	Branding Decision	1. Major Brand Concepts and branding Decision 2. Managing Brand Equity and Loyalty

VI. Theory

Block 1: Introduction

Unit 1: Introduction to Advertising Management: Integrated Marketing Communications, Setting Goals and Objectives, How advertising works: Segmentation and Positioning Assess the strengths, weaknesses, opportunities and threats (SWOT) of different kinds of promotional campaigns

Unit 2: Message Strategy: Attention and comprehension, Advertising appeals, Associating Feelings with the Brand, Brand Equity, Image and Personality and Group Influence and word of month advertising, Media Planning and Media Strategy, Media Strategy and Tactics, Legal, Ethical and Social concerns of Advertising.

Unit 3: Consumer Promotions and Trade Promotions: Their purpose and types How to plan and evaluate a successful promotion, The relationship between advertising and promotions, Introduction to Global Marketing, Advertising and sales promotion.

Block 2: Branding Decision

Unit 1: Major Brand Concepts and branding Decision: Identifying and selecting brand name Building brand personality, image and identity; Brand positioning and re-launch; Brand extension; Brand portfolio; communication for branding Enhancing brand image through sponsorship and even management.

Unit 2: Managing Brand Equity and Loyalty: Brand Building in Different Sectors - Customers, industrial, retail and service brands. Building brands through Internet, social Media. Building Indian brands for global markets.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

This course investigates various promotional tools used in the communication mix, such as advertising, sales promotion, and publicity, to sell products and services. Concepts include: advertising planning processes, determining advertising and promotional goals and objectives, control and evaluation of advertising and promotional programs, and regulatory issues. Students will develop a comprehensive advertising campaign for a real or imaginary product.

IX. Suggested Reading

- Keller KL. *Strategic Brand Management;* Pearson education, New Delhi Verma, Harsha*: Brand Management;* Excel Books; New Delhi
- Kapferer JN. *Strategic Brand Management;* Kogan Page; NewDelhi
- Kumar S. Ramesh; *Marketing and Branding–The Indian Scenario;* Pearson Education; New Delhi Kapoor, Jagdeep; *24 Brand Mantras*, Sage Publications; New Delhi
- Sengupta S. *Brand Positioning: Strategies for competitive advantage*; Tata McGrawHill; New Delhi.
- Clifton R and Simmons J. *Brands and Branding*; The Economist; Delhi

I. Course Title : Agri Infrastructure and Waregousing Management

II. Course Code : ABM 532

III. Credit Hours : 1+0

IV. Why this course?

To create a pool of Agricultural storage infrastructure, logistics and warehouse professionals with capacity to manage agri-warehouse operations efficiently includes the overall inventory turnover and working capital management.

V. Aim of the course

The course provides an introduction to the key principles and activities related to the warehousing function in a modern organization designed for receiving, shipping, picking, packing etc. It also includes cold chain project, logistics awareness & training programs.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Agricultural Infrastructure in India 2. Warehouse Functions: 3. Warehouse Types, Characteristics
2.	Warehouse Management	1. IT for Warehouse Management (WM): 2. Agri-warehousing Management in India

VI. Theory

Block 1: Introduction

Unit 1: Agricultural Infrastructure in India: Incentive schemes, Agri-infra fund, Agri-market Infrastructure, Agri-technological infrastructure fund, Central Government policy on Infrastructure promotion for the development of primary sector such as Irrigation, Watershed development, Rural electrification, Connectivity, Communication and Markets in coordination with the Institutional framework.

Unit 2: Warehouse Functions: Meaning of Warehousing - Importance –Functions:

Receiving: Logistics support for Inward Transportation, Unloading, Inspection, Acceptance and Recording; Storing: Space allocation, Facilitation to stocking, Guarding &Recording; Risk bearing- Processing- Grading and branding – Disinfecting services -Issuing: Order preparation, Picking, Dispatching/ Delivery & Recording- Handling, Transportation & Storage of ISO Containers– Utility and Advantages of warehouses- Problems and issues in receiving processes.

Unit 3: Warehouse Types, Characteristics: Warehouse Types, Characteristics of ideal warehouses- Warehouse Layout-Principles and Facilities- Types, Internal Operations: Measures and metrics of warehouse operations, Logistics in the warehouse- Localization of materials in a warehouse, Identification and classification of Materials and products in the warehouse, Managing the material/products turns in warehouse (FIFO/LIFO) - Problems and issues in shipment processes. Warehousing Equipment, Inventory management.

Block 2: Warehouse Management

Unit 1: IT for Warehouse Management (WM): Warehouse documentation- Information flows in the warehouse- ERP-WMS - Bar code – RFID- Organization Data- Warehouse Structure- Warehouse Master Data - WM Material master view- Organization Data- Define Warehouse structure, Warehouse number - Storage type- Storage section - Storage Bin - Picking Area -Storage unit – Quantity- Creating Transfer requirement automatically/ manually – Creating Transfer requirement for storage.

Unit 2: Agri-warehousing Management in India: Agri-warehousing in India, capacity development and utilisation, Role and significance of Central Warehousing Corporation, State warehousing Corporation, Private sector in Agri-warehousing. Status of Warehousing Industry:

Agri-warehousing organisations in India, e-NAM to promote agri-warehouse.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To study the status of development of Agricultural infrastructure as well as the role of Warehouses to boost Agricultural sector.

IX. Suggested Reading

- Study materials of NABARD as well as by the Ministry of Rural development
- Edward F. 2001. *World-Class Warehousing and Material Handling,* McGrraw Hill
- Jeroen P. Van Den Berg. 2009. *Integral Warehouse Management*, Management Outlook Max Muller. 2009. *Essentials of Inventory Management*. AMACOM
- Steven M. Bragg. 2011. *Inventory Best Practices*. Wiley

I. Course Title : Contract Farming

II. Course Code : ABM 533

III. Credit Hours : 1+0

IV. Why this course?

To assess the need of Contract farming arrangement . It relates to agricultural production carried out according to an agreement between a buyer and farmers, with set conditions for production and marketing of farm products.

V. Aim of the course

The course provides an agreement between a farmer and a buyer. At the same time, the buyer also needs to provide the farmer with the necessary inputs required for the farm like land preparation, technical aspects etc. It is an effective means to develop markets and bring about crop rotation.
The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Need for contract farming 2. Project formulation and management
2	Policies, prospects and global issues	1. Policies for promoting contract farming 2. Prospects of contract farming in India 3. Global issues

VI. Theory

Block 1: Introduction

Unit 1: Need for contract farming: objectives and its definition; contract farming framework, contract farming arrangement-centralized model, nucleus estate model, multipartite model, informal model, intermediary model.
Unit 2: Project formulation and management: Coordination, crop husbandry, human resource. Advantages of contract farming for farmers and sponsors and the problems faced by them.

Block 2: Policies, Prospects And Global Issues

Unit 1: Policies for promoting contract farming: Agreement for contract farming-parties, duration, produce and quality specification, delivery arrangements pricing, insurance, support services, etc.
Unit 2: Prospects of contract farming in India: Prospects of contract farming in India in view of interest for commercialization of agriculture. Active organizations in contract farming and their success stories.
Unit 3: Global issues: lobal issues in contract farming, Contract farming and WTO agreement

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To provide the students an understanding of concepts, policies, strategies and decisions relating to marketing that can be associated with agribusiness organizations. It involves agricultural production being carried out on the basis of an agreement between the buyer and farm producers. The farmer undertakes to supply agreed quantities of a crop or livestock product, based on the quality standards and delivery requirements of the purchaser.

IX. Suggested Reading

- Sharma P. 2007, C*ontract Farming*, Genetech Books

- Kuzilwa JA, Fold A, Henningsen A and Larsen MN. *Contractfarming and the development of smallholder* agricultural business. Routledge
- Kumaravel KS 2006. *Contract farming in India* - An Introduction.

I. Course Title : Human Resource Competence and Capacity Building Systems

II. Course Code : ABM 534

III. Credit Hours : 1+0

IV. Why this course?

Capacity development is the process by which individuals and organizations obtain, improve, and retain the skills, knowledge, tools, equipment and other resources needed for Human resource development.

V. Aim of the course

This course is designed to provide an in-depth understanding and enable the participants to manage capacity building processes and performance system for developing human resource.

The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Human Resource competence 2. Competency modelling and assessment
2	Capacity building	1. Competency based training and development 2. Performance Management System 3. Capacity building systems in agriculture and agri business

VI. Theory

Block 1: Introduction

Unit 1: Human Resource competence: Concept and rationale; processes, Organization and Management of competence and competency mapping.

Unit 2: Competency modelling and assessment: Approaches, tools and techniques, competency based human resource management applications.

Block 2: Capacity Building

Unit 1: Competency based training and development: Training methods compared with objectives, learning process and facilities, Developing Group and the Climate: the social process – indicators of group development, the training climate, Trainers And Training Style: Post training support for improved performance at work.

Unit 2: Performance Management System: Establishing and operationalising performance management system; measuring performance- results and behaviour; conducting performance review discussions; harnessing performance management system for performance improvement.

Unit 3: Capacity building systems in agriculture and agri business: Capacity building of farmers and agri stakeholders through e-learning, knowledge management for agri business.

VII. Teaching methods/activities

- Lecture and Discussion

- Case Study
- PPT presentation

VIII. Learning outcome

Proactive human resources management is essential to achieve the excellence through Capability Development and Planning. A Competence Profile for Staff Supporting the formal and informal training, job-rotation, traditional class-room courses, internal vs external training.

IX. Suggested Reading

- Kandula SR. 2013. *Competency Based Human Resource Management*. PHI
- Noe RA and Kodwani AD. 2012. *Employee Training and Development*. McGraw Hill Education. Fifth Edition
- Saks AM and Haccoun RR. 2013. *Managing Performance through Training and Development*. Cengage Learning. Sixth Edition

I. Course Title : Agri-Commodity Markets and Futures Trading

II. Course Code : ABM 535

III. Credit Hours : 1+0

IV. Aim of the course

To make the students understand the marketing procedure for commodity futures through commodity exchanges

The course is organized as follows:

No	Blocks	Units
1.	Overview of Commodity Market in India	i. Price risk management in agricultural markets ii. Global Specifications of futures contracts
2.	Mechanics of futurestrading	i. Option and forward transaction ii. Clearinghouse and margin system
3.	Market surveillance and risk control	i. trading in warehouse receipts ii. Regulation of futures and trading practices in leading national and regional exchanges in India

V. Theory

Block 1: Overview Of Commodity Market In India

Unit I: Introduction to commodity derivatives and price risk management in agriculturalmarkets; organizational setup of exchanges and specifications of futures contracts in world's leading commodity exchanges

Block 2: Mechanics of Futures Trading

Unit II: Futures trading; hedging price risk using futures contracts; option transaction andforward transaction – concept and mechanism, price discovery mechanism and market efficiency

Unit III: Clearinghouse and margin system; clearing, settlement and delivery of contracts

Block 3: Market Surveillance and Risk Control

Unit IV: Market surveillance and risk control; trading in warehouse receipts (WRs):

WRs andcollateralized commodity financing

Unit V: Regulation of futures and trading practices in leading national and regional exchangesin India.

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Get an overview about the commodity markets in India
– Understand the mechanics of futures trading practices
– Know about the risk and surveillance mechanism available for agri commodity trading in India

VIII. Suggested Reading

- Hull, John C. 2017. *Fundamentals of futures and options markets*, Boston, Pearson publication.
- Ram PV and Bala SD. 2016. *Strategic Financial Management*. Snow White Publ. 80.

I. Course Title : Strategic Management for Agri Business Enterprises
II. Course Code : ABM 536
III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to provide students a strategic orientation in conduct of the business and to develop a holistic perspective of an organization and to enable the students to analyse the strategic situation strategies in general and functional management areas.
The course is organized as follows:

No	Blocks	Units
1.	Overview of Strategic Management	1. Strategic management process 2. Environment scanning and industry analysis 3. Value Chain Analysis
2.	Strategy Formulation and Choice	1. Strategy formulation 2. Types of strategies 3. Strategic analysis tools and techniques
3.	Strategy implementation and control	1. Strategy implementation and control 2. Entrepreneurial ventures and small businesses

V. Theory

Block 1: Overview Of Strategic Management

Unit I: Introduction - Concepts in Strategic Management, Strategic Management Process; Corporate Governance, Social Responsibility and Ethics in strategic management, Environment Scanning and Industry analysis

Block 2: Strategy Formulation And Choice

Unit II: Organization appraisal and strategy formulation: organizational dynamics andstructuring organizational appraisal, business models and Value chain analysis, Strategy formulation- corporate level strategies and business strategies, Generic Strategies- Types of Strategies, tools and techniques for strategic analysis.

Unit III: Turnaround and Diversification Strategies: Turnaround strategy - Management ofStrategic Change, Strategies for Mergers, Acquisitions, Takeovers and Joint Ventures - Diversification Strategy

Block 3: Strategy Implementation And Control

Unit IV: Strategy implementation and control: aspects, structures, design and change: behavioural implementation-leadership, culture, value and ethics, strategic evaluation and control-an overview and techniques of strategic evaluation and control.

Unit V: Strategic issues in managing technology & innovation, entrepreneurial ventures andsmall businesses, Cases in strategic management

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Define the strategic management process and scanning of internal and external environment
– Get a clear picture about value chain analysis
– Understand the different types of strategic choices available and the method of analysis to choose the best among them
– Learn the method of strategic implementation and evaluation for agr entrepreneurial ventures

VIII. Suggested Reading

- Wheelen TL and Hunger JD. 2012. *Strategic Management & Business Policy, towards Global Sustainability*, Pearson India Edn. Thirteenth Edition
- David FR and David FR. 2016. Strategic Management, Concept and Cases, Pearson India Edn, Fifteenth Edition
- Thompson Jr. AA, Peteraf M and Gamble JE. 2015. *Crafting and Executing Strategy*. McGraw Hill, Irwin.
- Stead JG and Stead EW. 2014, *Sustainable Strategic Management*. Routledge Taylor & Francis Group.
- Kazmi Azhar. 2015. Strategic Management. Mcgraw Higher Ed. 4th Edition
- Srinivasan R. 2014. Strategic Management. PHI Learning 5th Edition

I. Course Title : Operations Management

II. Course Code : ABM 537

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint the students with the applications of important operations research

techniques for better understanding to solve business problems.
The course is organized as follows:

No	Blocks	Units
1.	Introduction to Linear Programming	1. Formulation of Linear Programming problem 2. Methods of solving linear programming problem 3. Transportation and Assignment problems
2.	Inventory control and waiting line models	1. Types of inventory and inventory costs
3.	Decision making under risk and uncertainty	1. Decision problem 2. Decision trees

V. Theory

Block 1: Introduction to Linear Programming

Unit I: Linear Programming: Objective, Assumptions, Formulation of Linear Programming Problem, Data Envelopment Analysis, Graphic Method, Simplex method, Introduction to Dynamic Programming, Transportation and Assignment Problems.

Block 2: Inventory Control And Waiting Line Models

Unit II: Inventory control Models: Costs Involved in Inventory Management, Types of Inventory, Economic Order Quantity (EOQ) Model, Continuous Review (Q) System, Periodic Review (P) System, and Hybrid System.

Unit III: Waiting Line Models: Waiting Line Problem, Characteristics of a Waiting-Line System, Single- Channel Model, Multiple-Channel Model, Constant-Service Time Model, Finite Population Model, Sequencing and Replacement models.

Block 3: Decisionmaking Under Risk and Uncertainty

Unit IV: Decision making under Risk and uncertainties, Decision problem, Maximax Criterion, Maximin Criterion, Minimax Regret Criterion, Laplace Criterion, Pay off Tables, Decision Trees, Expected Value of perfect Information, stochastic models, neural networks, Markov process.

Unit V: Game Theory - Two -Person Zero-Sum Game, Simulation, Network analysis– PERT& CPM. Financial Engineering

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Knowledge and understanding about the characteristics of different types of decision-making environments and the appropriate decision making approaches and tools to be used in each type.
– Develop cognitive skills (thinking and analysis) to build and solve Transportation Models and Assignment Models

VII. Suggested Reading

- Taha HA. 2007. *Operations Research - An Introduction*. Prentice Hall.
- Vohra ND. 2017. *Quantitative Techniques in Management*. 5th Edition McGraw Hill.
- Wagner HM. 2005. *Principles of Operation Research*. Prentice Hall.

I. Course Title : Financial Management in Agribusiness
II. Course Code : ABM 538
III. Credit Hours : 2+0

IV. Aim of the course

To impart trainings to the students regarding various aspects of sources of financing agribusiness.

The course is organized as follows:

No	Blocks	Units
1.	Financial management in India	1. Agribusiness Financing in India 2. Risk and return concept and analysis 3. Money and Capital Markets 4. International financial management
2.	Capital budgeting	1. Techniques of capital budgeting decision 2. Cost of Capital 3. Sources of Long and Short term finance
3.	Current assets management	1. Management of Working Capital 2. Perspectives and operational aspects of Micro finance

V. Theory

Block 1: Financial Management In India

Unit I: Meaning, importance, nature and scope of financing in India, agribusiness financing inIndia; classification and credit need in changing agriculture scenario; finance functions, investment financing, Risk and return concept & analysis

Unit –II: Business Financing System in India, Money and Capital Markets, Regional and All -India Financial Institutions; venture capital financing and its stages, International financial management.

Block 2: Capital Budgeting

Unit III: Features, types and Techniques of capital budgeting decision. Cost of Capital, Leverage analysis, Capital structure. Theory and Policy, Sources of Long and Short term finance, Dividend Theory, Dividend Policy.

Block 3: Current Assets Management

Unit IV: Management of Working Capital, Management of Receivables, Management of cash; Cash budget, Management of collections and disbursement, Investment of Surplus cash.

Unit V: Perspectives and operational aspects of Micro finance**:** Definition, Scope andimportance of Micro Finance, Evolution of Micro Finance in India, Micro Finance credit lending models: - Association model, Community Banking model, Credit union model, Co-operative model, SHG model, Village Banking model.

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the financial management practices in India
- Know about the concepts capital budgeting and cost of capital
- Understand the major sources of financing in India and their implications for a agri-based organization

VIII. Suggested Reading

- Nelson AG & Murrey WG. 1988. *Agricultural Finance*. Kalyani Publ.
- Gordon and Natarajan. 2016. *Financial Markets and Services*. Himalaya Publishing House; Tenth Edition
- Machiraju HR. 2010. *Indian Financial System*. Vikas Publishing House
- Pandey IM. 2015. *Essentials of Financial Management*, Vikas Publishing House
- Khan and Jain. 2014. *Financial Management*. McGraw Higher Education
- Srivastav and Misra. 2010. *Financial Management*, Oxford University Press; Second edition
- Reddy GS. 2010. Financial Management, Himalaya Publishing House

I. Course Title : Communication for Management and Business

II. Course Code : ABM 539

III. Credit Hours : 3+0

IV. Aim of the course

The course aims to make students proficient in written as well as in oral communication with focus on business related communication.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Business Communication	1. Communication process, barriers and methods 2. Types of business communication 3. Developing listening skills 4. Non verbal communication
2.	Reading and writing skills	1. Reading Comprehension and techniques 2. Business writing skills 3. Messages for electronic media
3.	Oral and visual communication Technical writing skills	1. Oral presentation skills 2. Public speaking skills
4.	Team and Interpersonal communication	1. Effective Interpersonal Communication 2. Business etiquettes 3. Problem solving skills 4. Case method of learning

V. Theory

Block 1: Introduction to Business Communication

Unit I: Communication process, barriers to communication, methods of communication, effective communication, assertive communication, types of organisational communication. Listening skills, active listening, barriers to effective listening, Non Verbal Communication

Block 2: Reading And Writing Skills

Unit II: Reading comprehension and techniques, rules of good writing, business letter writing, e-mail writing, crafting messages for electronic media, social media, business blogs, podcasts, employment messages

Block 3: Oral, Visual Communication and Technical Writing

Unit III: Visual presentation, oral presentation skills, conducting business meetings, brainstorming sessions and presentations, public speaking skills, Communicating across cultures, Various forms of scientific writings, theses, technical papers, reviews, manuals, research work, various parts of thesis and research communication Title page, authorship, contents, preface, introduction, review of literature, material and methods, experimental results and discussion, Technical Writing Style and Editing, Writing Introductions & Conclusions, Editing and Proof reading, Writing a review article and book summary

Block 4: Team And Interpersonal Communication

Unit IV: Developing interpersonal skills (transactional analysis), Business Etiquettes, essentials of business conversations. Business meeting agenda and minutes, circulars and sales letters, notices, overview of business proposals

Unit V: Developing self awareness (Johari Window), solving problems analytically andcreatively, introduction to case method of learning, case reading, approaches and analysis

VI. Teaching methods/activities

- Interactive sessions to make the participants practice communication skills
- Group and individual presentations followed by feedback
- Live projects to study the challenges faced in the organsiational communication setup
- Make the participants practice communicating on social media platforms to write blogs, make and upload videos
- Self awareness assessment based questionnaires
- Case studies to develop interest and understanding of solving real life situation analytically and creatively

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the concepts of business communication
– Practice listening, reading writing and presentation skills
– Develop clarity about the method of handling team and interpersonal communication effectively

VIII. Suggested Reading

- Cardon PW. 2015. *Business Communication, Developing leaders for a networkedworld* Mc Graw Hill Edication
- Chaturvedi PD and Chaturvedi M. 2017. *Business Communication, Skills, Concepts, Cases and Applications*, Pearson India Education
- Bovee CL, Thill JV and Chaterjee A. 2013. *Business Communication Today*, Pearson Education, Tenth Edition

I. Course Title : Research Methodology for Agri Business Management
II. Course Code : ABM 540
III. Credit Hours : 3+0

IV. Aim of the course

To develop an understanding of research methodology related to efficient agri business management

The course is organized as follows:

No	Blocks	Units
1.	Overview of research	1. Research methodology in management 2. Scales of measurement 3. Questionnaire designing
2.	Use of softwares for statistical analysis	1. Multivariate statistical analysis 2. Evaluation metrices 3. Forecasting Techniques
3.	Data science in agriculture	1. Introduction to data science in agriculture 2. Overview of deep learning and machine learning 3. Concept of cloud machine learning

V. Theory

Block 1: Overview of Research

Unit I: Meaning, Course Objective, types, and process of research; research methodology inmanagement- exploratory, descriptive, experimental, diagnostic, Problem formulation, setting of Course Objective, formulation of hypotheses, models, types of models, process of modeling.

Unit II: Scales of measurement - nominal, ordinal, interval, ratio, Likert scale and other scales; Primary and secondary data, sources of data, Questionnaire Designing, instruments of data collection, data editing, classification, coding, validation, tabulation, presentation, analysis, development process of scale, identification of variables, variable measurement, variable standardization and dummy variables.

Block 2: Use of Softwares for Statistical Analysis

Unit III: introduction to multivariate statistical analysis techniques, Multivariate linearregression models, principal component analysis, linear discriminant analysis, factor analysis, evaluation matrices and model diagnostics for regression models.

Unit IV: Logistic regression, decision trees, cluster analysis, random forest, GARCH, CARTmodels, support vector machines, Forecasting techniques (AR, MA, ARMA and ARIMA models)

Block 3: Introduction to Data Science

Unit V: Definition, scope and importance, machine learning, types of machine learning, linearand nonlinear models in machine learning, introduction to deep learning, basic differences in machine learning and deep learning, concept of cloud machine learning, Big data analysis.

VI. Teaching methods/activities

- Interactive lectures

- Group assignments
- Presentations
- Live projects for marketing research problems
- Case study on application of marketing research tools

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand research methodology concepts along with its application in marketing research
- Develop insights about the statistical analysis tools and techniques for better research outcomes
- Understand the concept of and usage of data science, big data analysis for agriculture

VIII. Suggested Reading

- Cooper DR and Schindler PS. 2006. *Marketing Research Concepts and Cases*. TMH
- Kumar R. 2014. *Research Methodology,* Sage publications, 4th Edition
- Glenn JC. 2010. *Hand book of Research Methods.* OXFORD.
- Kothari CR. 2018. *Research Methodology- Methods and Techniques.* New Age International Publishers; Fourth edition

I. Course Title : Computer Applications for Agri Business

II. Course Code : ABM 541

III. Credit Hours : 3+0

IV. Aim of the course

The course aims to instill the significance of computer applications in the organizations and handling recent trends in information technology and system for improved decision making

The course is organized as follows:

No	Blocks	Units
1.	Basics of computers	1. Concept of computers 2. System and application softwares 3. Data base management system
2.	Business value of internet	1. Cloud computing 2. Cyber security and ethical challenges
3.	Management Information System	1. Concept of MIS 2. Introduction to Artificial Intelligence 3. E-commerce agri business trends

V. Theory

Block 1: Basics Of Computers

Unit I: Concept of Computers- Brief History of Computers, Generation and Its Evolution, Characteristics of Computers, Main Areas of Computers and their Applications; Classification of Computers, Input-Output Devices, Memory Types (Cache, RAM, ROM), Memory Units,

Unit-II: System Software and Application Software, Open source software, introduction tocomputer languages, Introduction to Operating Systems – Functions, Features and Types., MS Windows and LINUX. Data Base Management System, MS Office (MS Word, MS Power Point, MS Excel, MS-Access and use of various management software Like SPSS, SAS etc.

Block 2: Business Value Of Internet

Unit III: The business value of internet, Intranet, extranet and Internet, Introduction to Web page design using HTML, Cloud Computing, Security and ethical challenges: Computer crime – Hacking, cyber theft, unauthorized use at work. Piracy – software and intellectual property. Health and Social Issues, Ergonomics and cyber terrorism.

Block 3: Management Information System

Unit IV: The concept of MIS–Definition, importance, Course Objective, pre-requisites, advantages and challenges; Information Needs of organization, MIS and Decision – Making. Types/Classification of Information System for organizations; Introduction to Artificial Intellignce (AI), Neural Networks, Fuzzy logical control systems.

Unit V: e-business/ e-commerce: e-business models, e-commerce processes, electronic paymentsystems, e-commerce trends with special reference to agri business. Applications of MIS in the areas of Human Resource Management, Financial Management, Production/Operations Management, Materials Management, Marketing Management.

VI. Teaching methods/activities

- Lectures
- Practicals
- Live project
- Assignments
- Presentations

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the fundamentals of computers
– Get a clearer idea about the application of Information technology in agri business management
– Use of e commerce, artificial intelligence and MIS for improved decision making in management

VIII. Suggested Reading

- Laudon KC and Laudon JP. 2016. *Management Information Systems- Managingthe digital Firm,* 14h Edition, Pearson India
- Turban, Volonino, Woods. Wali OP. 2015. *Information Technology for Management, Advancing Sustainable, Profitable Business Growth*, Wiley
- Jaiswal M and Mittal M. 2005. Management Information System, Oxford.

I. Course Title : Project Management and Agribusiness Entrepreneurship

II. Course Code : ABM 542

III. Credit Hours : 2+1

IV. Why this course?

This course aims at providing student an insight into the nature of small scale industry. They will be exposed to various aspects of establishment and management of a small business unit.

The course is organized as follows:

No	Blocks	Units
1.	Concept of Project Management	1. Introduction to project management 2. Project feasibility 3. Network methods and project scheduling
2.	Introduction to Agri Entrepreneurship	1. Concept of agri entrepreneurship 2. Creativity, Innovation and Agro Entrepreneur
3.	Support System for Agri Entreprenuership	1. Sources of Financing for entrepreneurs 2. Preparation of Detail Project Report 3. Structure and Government Policy Support

V. Theory

Block 1: Concept of Project Management

Unit I: Concept, characteristics of projects, types of projects, project identification, and Project's life cycle. Project feasibility- market feasibility, technical feasibility, financial feasibility, and economic feasibility, social cost-benefit analysis, project risk analysis.

Unit II: Network Methods: Meaning, Network Analysis, Critical Path Method (CPM), Programme Evaluation and Review Technique (PERT), Project scheduling and resource allocation. Financial appraisal/evaluation techniques- discounted/non-discounted cash flows; Net present values, profitability index, Internal rate of returns; Cost benefits ratio; Accounting rate of return, Payback period, Project implementation; Cost overrun, Project control and information system.

Block 2: Introduction to Agri Entrepreneurship

Unit III: Concept of Agri Entrepreneurship**:** Objective, Introduction to agri entrepreneurship, Entrepreneurial Development Models, Successful Models in Agro Entrepreneurship Intrapreneur, Development of women entrepreneurship with reference to SHGs, Social entrepreneurship

Unit IV: Creativity, Innovation and Agro Entrepreneur: Inventions and Innovation, The Environment and Process of Creativity, Creativity and the Entrepreneur, Innovative Approaches to Agro Entrepreneurship, Business Incubation, Steps and Procedure to start a new business, Business Opportunities in different field of Agriculture and Allied Sectors.

Block 3: Support System For Agri Entreprenuership

Unit V: Sources of Financing, Structure and Government Policy Support: Estimating FinancialRequirements, Preparation of Detail Project Report, Project Appraisal, Sources of Long-Term Financing, Working Capital Financing, Venture Capitalist, Finance from Banking Institutions, Industrial Policy Resolutions in India, Incentives and Subsidies, Schemes for Incentives, Government Organisations like SIDO, DIC, KVIC, NSIC, SIDBI, NABARD and their role, Sick Industries and their Up gradation policy measures

VI. Teaching methods/activities

- Interactive lectures

- Live project in association with innovative farmers/ agri entrepreneur
- Cases related to agri entrepreneurship
- Guest lectures by bankers, entrepreneurs, academicians and venture capitalist firms
- Assignments
- Presentations of Agri Business Plans

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the fundamentals of project management
- Develop a understanding of agri entrepreneurship opportunities and challenges
- Understand the method of developing a agri based venture through the support system available in the Indian scenario

VIII. Suggested Reading

- Arora R and Sood SK. *Fundamentals of Entrepreneurship and Small BusinessManagement*. Kalyani Publishers, Ludhiana.
- Desai V. 2016. *Business Planning and Entrepreneurial Management*, Himalaya Publishing House, Mumbai.
- Ramachandaran K. *Managing a New Business Successfully*. Global Business Press, New Delhi.
- Shukla MB. *Entrepreneurship and Small Business Management*. Kitab Mahal, New Delhi.
- Dandekar VM and Sharma VK. 2016. *Agri-Business and EntrepreneurshipDevelopment*. Manglam Publications, New Delhi.
- Zimmerer TW, Scarborough NM. *Essentials of Entrepreneurship and small Business Management,* 5thEdition, PHI Learning Pvt Ltd
- Panigrahi SR and Singh B. 2017. *Agro Entrepreneurship*. Scientific Publishers(India)

I. Course Title : Agribusiness Environment and Policy

II. Course Code : ABM 543

III. Credit Hours : 2+0

IV. Aim of the Course

To expose the students to the environment in which the agri-business is conducted. The course is organized as follows:

No	Blocks	Units
1.	Agribusiness in India	1. Agri business environment in India 2. Major sub sectors of agri business in India
2.	Economic reforms affecting agri-business	1. Policies and regulations affecting agri business in India 2. WTO Agreement on Agriculture and its compliances
3.	Emerging trends in agri Business	1. Reforms in agri output markets 2. International trade in agri business 3. Food safety and quality management

V. Theory

Block 1: Agribusiness in India

Unit I: Role of agriculture in Indian economy; Problems of agriculture in India;

Agribusiness–definition and nature, Structure of Agriculture and linkages among sub-sectors of the agribusiness.

Block 2: Economic Reforms Affecting Agri Business

Unit II: Economic reforms: liberalization, privatization and globalization specifically affectingAgri Business; WTO Agreement on Agriculture and its compliances; changes in policies and regulations related to the sub sectors of agribusiness and its impact on agribusiness in India.

Block 3: Emerging Trends in Agri Business

Unit III: Emerging trends in farm supplies, farm production, agricultural finance, agroprocessing, international trade etc.; reforms in agri output markets: private markets, contract farming, futures trading in agri commodities and e-NAM, etc. Pricing of agricultural outputs, public distribution system, imports and exports.

Unit IV: Importance of food safety and quality management in agri business; Environmentalissues and including carbon markets and Clean Development Management etc.

Unit V: Other major issues: Intellectual property rights, importance of cooperative or collectiveactions in present scenario with examples of mergers and acquisitions, Farmers Producer Organisations, etc.

VI. Teaching methods/activities

- Lectures
- Role plays
- Case studies as group assignment
- Presentations
- Assignments
- Live projects

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Develop an understanding about the role and problems agriculture and agri business is playing in the Indian economy
– Critically evaluate the major economic reforms that have directly or indirectly affected agri business in India
– Understand the emerging trends and challenges in the field of agri business

VIII. Suggested Reading

- Barnard FL, Akridge JT, Dooley FL, Foltz JC and Yeager EA. 2012. *Agribusiness Management*, Routledge, 4th Edition
- Aswathappa K. 2014. *Essentials of Business Environment*. Himalaya Publ.
- Francis Cherunilam 2003. *Business Environment*. Himalaya Publ.
- Kodekodi GK and Viswanathan B. 2009. *Agril. Development, Rural Institution & Economic Policy*, Oxford.

I. Course Title : Agri Business Laws and Ethics

II. Course Code : ABM 544

III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to expose the learner to various ethical issues and laws affecting business. Focus will be on understanding provisions of various business laws with reference to agriculture and also ethical practices to conduct the business properly.

The course is organized as follows:

No	Blocks	Units
1	Indian Legal System	1. Indian Contract Act 3. Companies Act
2.	Regulatory environment for agri-business	1. Essential Commodities Act 2. Consumer Protection Act
3.	Business ethics	1. Ethics in agri business functional areas 2. Governance mechanism

V. Theory

Block 1: Indian Legal System

Unit I: Introduction to Indian legal system, The Indian Contract Act-1872: Contract meaning, types of contract, essentials of a valid contract, offer and acceptance, capacity to contract, free consent, performance of contract.

Unit-II: Law of Negotiable Instruments: Promissory Notes, Bills of Exchange, Cheques and Bank Drafts, Endorsements, Law of Sale of Goods, Sales of Goods Act-1930-: Sale and agreement to sale, types of goods, Transfer of property in goods, mode of delivery of goods, performance of contract of sales, rights of an unpaid seller.

Unit III: Companies Act-1956: incorporation, commencement of business, types of companies, management of company, Memorandum of Association and Articles of Association, prospectus, winding of companies.

Block 2: Regulatory Environment For Agri Business

Unit IV: Essential Commodities Act, Consumer Protection Act, RTI Act, MRTP Act- majorprovisions and implications. Competition Act-2002, Regulatory environment for International Business

Block 3: Business Ethics

Unit V: Nature and importance of ethics and moral standards; corporations and socialresponsibilities, scope and purpose of business ethics; Ethics in business functional areas; industrial espionage; solving ethical problems; governance mechanism. implementing business ethics in a global economy

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Learn about the Indian legal system that directly affects the agri business in India
– Know about the regulatory framework in which the agri business is to be conducted and managed
– Understand the importance of practicing business ethics

VIII. Suggested Reading

- Mathur SB. 2010. *Business Law*. Tata McGraw Hill Edn. Pvt Ltd.
- Gulshan SS and Kapoor GK. 2003. *Business Law including Company Law*. 10th Ed. New Age Publ.
- Kapoor ND. 2005. *Business Law*. S. Chand & Sons.
- Tuteja SK. 2005. *Business Law for Managers*. S. Chand & Sons.
- Tulsian PC and Tulsian B. 2015. *Business Law*. TMH, New Delhi.
- Singh Avtar. 2017. *Contract and Specific Relief,* Eastern Book Company; Twelfth edition
- Pathak A. 2015. *Legal Aspects of Business*. McGraw Hill Education. 6th Edition

Course Title with Credit Load
Ph.D. in Agri-Business Management

Course Code	Course Title	Credit Hours
	Major Courses	**12**
ABM 601	Econometrics for Agri Business	3 (2+1)
ABM 602	Research Methods I	3 (2+1)
ABM 603	Agri Input & Output Marketing	3 (2+1)
ABM 604	Research Methods II	3 (2+1)
	Minor Courses	**6**
ABM 605	Natural Resource Management	2+0
ABM 606	Knowledge Management	2+0
ABM 607	Value Chain Management in Agribusiness	2+0
	Supporting Courses	**5**
ABM 608	Agri-Entrepreneurship and Corporate Governance	1+0
ABM 609	International Food and Agri Business	2+0
ABM 610	Communication for Management Teachers	0+2
	Seminars	**2**
	Doctoral Seminar I	1(1+0)
	Doctoral Seminar II	1(1+0)
	Research	**75**
	Total	**100**

Course Contents
Ph.D. in Agri-Business Management

I. Course Title : Econometrics for Agri-Business

II. Course Code : ABM 601

III. Credit Hours : 2+1

IV. Aim of the course

The course is mainly designed to solid data base analysis of market and policy variables to back up their business strategies. The emphasis will be given on application rather than theoretical details.

The course is organized as follows:

No	Blocks	Units
1.	Formulation and specification of econometric models	1. Simple Regression Analysis 2. Properties of Regression Coefficients and Hypothesis Testing 3. Multiple Regression Analysis 4. Heteroscedasticity 5. Stochastic Regressors and Measurement Errors 6. Simultaneous Equations Estimation
2.	Estimation and testing of models	1. Modelling Dynamic Processes 2. Autocorrelation 3. Logit and Probit (binary choice models)

V. Theory

1. Introduction: Correlation theory, Basic concept of regression analysis, assumptions of regression model, theory of OLS, properties of least square estimates, maximum likelihood, hypothesis testing, interval estimation, prediction in linear regression model.
2. Heteroskedasticity and autocorrelation, multicollinearity, specification errors, selection of regressors, dummy variables, autoregressive and distributed models.
3. Set of regression equations, casuality and simultaneity: application.
4. Time series econometrics- stationarity, unit roots and co-integrassion, error-correction model, AR, MA, ARMA, ARIMA processes.
5. Qualitative dependent variables – LPM, Logit and probit models.

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Acquire the basic knowledge of econometrics
- Learn the basics of econometric models and testing its application in the agri business environment

VII. Suggested Reading

- Gujarati, Damodar, *Basic Econometrics*, McGraw-Hill Company
- James H. Stock and Mark W. Watson: *Introduction to Econometrics*, Pearson Education

I. Course Title : Research Methods-I

II. Course Code : ABM 602

III. Credit Hours : 2+1

IV. Aim of the course

The objective of the course is to enable research scholars in developing the knowledge and skills required to specify, evaluate and utilise different types of unstructured and semi-unstructured information. They are required to develop competence in problem formulation, hypothesis generation and method of carrying scientific research in situations where research work plays a critical role. The course is practical in nature and students are expected to learn by doing live projects and studying the latest researches in different fields related to agri business.

The course is organized as follows:

No	Blocks	Units
1.	Overview of Research Methodology	1. Research process 2. Problems and Hypotheses 3. Processing and analysis of data
2.	Introduction to business analytics	1. Types of Business Analytics 2. Introduction to predictive modelling/analytic

V. Theory

Block 1: Overview of Research Methodology

Unit 1: Translating problems to research issues: Selection of qualitative vs quantitative research definitions, objectives, research methodologies rationale, sample/sources of data, data collection techniques, Questionnaire designing: use of measurement and scaling techniques, reliability testing.

Unit 2: Fieldwork: Data collection, gaining access and entry, ethical considerations, identifying key informants, validation and evaluation of fieldwork, data preparation, field notes and recording

Unit 3: Hypothesis Development and Theoretical Modelling. Business Analytics, Business Intelligence,

Block 2: Introduction To Business Analytics

Unit 4: Types of Business Analytics, Introduction to predictive modelling/analytics. Linear programming, Contemporary applications of marketing research

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Learn about the basics of research methodology
- Understand the application of research for problem solving related to agri business environment

I. Course Title : Agri Input and Output Marketing

II. Course Code : ABM-603

III. Credit Hours : 2+1

IV. Aim of the course

Agricultural Input & Output marketing is a dynamic and competitive field where lot is to be done looking to the gap in technology existing and possible. Changes are taking place in manifolds ranging from farming practices to trading in domestic and international markets. Presence of private players, infrastructure development, impact on prices, concept of e mandietc are becoming more important to understand in current scenario. Scholars will also study the researches and articles to understand interesting changes going on in this field.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to agri input and out marketing environment	1. Current status of agri input and output markets in India 2. Marketing mix for agri inout and output marketing
2.	Evaluation of marketing costs and efficiencies	1. Assessment of different cost components 2. Case studies on various marketing strategies adopted by national and global players

V. Theory

Block 1: Introduction to Agri Input and Out Marketing Environment

Unit 1: Agriculture input and output marketing environment-Current status, trends, market structure, infrastructure, competition, Government intervention in agricultural inputs and outputs marketing

Unit 2: Buyers/users behavior, Market Segmentation, Product and Pricing, Promotion and advancement in promotional strategies, Marketing Channels for different agri inputs and outputs

Block 2: Evaluation of Marketing Costs and Efficiencies

Unit 3: Evaluation of marketing costs and efficiencies, WTO and Indian Agriculture, Case Studies- Competitive marketing strategies and advancements in agricultural marketing, International agri marketing practices

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Develop a understanding about the existing practices of agri input and output marketing in India
- Acquire a deep learning about assessing the marketing cost and related efficiencies to make the agricultural marketing profitable

I. Course Title : Research Method-II

II. Course Code : ABM 604

III. Credit Hours : 2+1

IV. Aim of the course

Once the students are equipped with the information required for interpretive research,

RM II will train the students with advanced analytical tools and their uses.
The course is organized as follows:

No	Blocks	Units
1.	Hypothesis testing	1. Analysis of variance and covariance 2. Multidimensional scaling and conjoint analysis
2.	Data Mining, Data Mining Methods	1. Data Mining Methods 2. Business Process Discovery
3.	Applications of Statistical Softwares	1. Modelling with statistical softwares, Report preparation and presentation

V. Theory

Block 1: Hypothesis Testing

Unit 1: Hypothesis testing, Analysis of variance and covariance, Correlation and regression, Discriminant and Logit analysis, Factor analysis, Cluster analysis, Multidimensional scaling and conjoint analysis.

Block 2: Data Mining

Unit 2: Data Mining, Data Mining Methods—Data Dredging, Data Fishing, Data Snooping and Process Mining—Business Process Discovery, Conformance Checking and Model Enhancement. Arena Modelling.

Block 3: Applications of Statistical Software

Unit 3: Applications of Statistical Softwares like SAS, Modelling with statistical softwares. Report preparation and presentation, International Marketing Research.

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the concepts of hypothesis testing
- Learn the application of statistical analysis softwares by hands on experience in agri business problem solving methods

VII. Suggested Reading

- Cohen L, Lawrence M and Morrison K. 2005. *Research Methods in Education* (5th edition). Oxford: Oxford University Press.
- Denscombes M. 2010. *The Good Research Guide: For small-scale social research projects*. Maiden-Read: Open University Press.
- Dornyei Z. 2007. *Research Methods in Applied Linguistics*. Oxford: Oxford University Press.
- Kothari CR. 1980. *Research Methodology: Research and Techniques*, New Delhi: New Age International Publishers.
- Kumar R. 2011. *Research Methodology: a step-by-step guide for beginners* (3rd edition).
- Singh YK. 2006. *Fundamental of Research Methodology and Statistics*. New International (P) Limited, Publishers, New Delhi.

I. Course Title : Natural Resource Management

II. Course Code : ABM 605

III. Credit Hours : 2+0

IV. Aim of the course

The course on Natural Resource Management will provide indepth knowledge to the participants to look for ways to make responsible natural resource management decisions which will have an impact on all stakeholders.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to natural resources	1. Types and classification of natural resource 2. Economic resource theory and applications
2.	Overview of Natural Resource Management	1. NRM sectors product marketing and their roles 2. Concept of environmental services 3. Ecotourism Policy and practices

V. Theory

Block 1: Introduction To Natural Resources

Unit-I Natural resources: Types and classification of natural resource, concept of Economic value, relevance of environmental economics, ecosystems services, direct and indirect economic benefit from – forest ecosystems, mountain ecosystems, mineral and water resources, ecotourism. Valuation and accounting: Supply and demand, conservation and management, cost/ benefit analysis, methods of costing, cost criteria, evaluating alternative projects, operational vs. total costs, determining benefiting vs. comprehensive stakeholders Application of resource accounting Methods of pricing resources- example forest and mineral resources.

Unit-II Economic resource theory and applications: Concept of CPR, open access, Ecological economics-methodology, economic valuation of non market benefits, environmental accounting, population resources and the environment, command and control vs. emission trading, emission trading vs. exposure trading, hotelling principle, future strategies for mineral resources.

Block 2: Overview of Natural Resource Management

Unit-III Natural Resource Management: Initial concept of market and marketing, NRM sectors product marketing and their roles, promoting NRM products- NTFPs, livestock, watershed, fisheries, agriculture and medicinal plants and ecotourism, Role of national and international organizations in the promotion of sustainable natural resource use and management.

Unit IV: Concept of environmental services: Definitions, ecotourism, alternative examples, development of ecotourism in India and outside. Threats due to large scale ecotourism. Payment for Ecosystem Services, the ecotourism dilemmas: High value may also be high impact, bulk ecotourism and problems, stakeholder challenges, tourist carrying capacity. Ecotourism Policy and practices, national policy frame work, example – Madhya Pradesh & Uttarakhand State case. Successful ecotourism initiative, Criteria and Indicators for sustainable Ecotourism.

VI. Suggested Reading

- Barber E. 1989. *Economics: Natural Resources Scarcity and Development*. Earthscan.
- Harris JM. 2006. *Environmental and Natural Resource Economics: A Contemporary Approach*, 2nd edition. Houghton Mifflin
- Field Barry C. 2008. *Natural Resource Economics: An Introduction*. Waveland Press.
- Honey Martha. 2008. Ecotourism and Sustainable Development: Who Owns Paradise? 2 nd edition. Island Press. 2. Seema Bhat & Syed Liyakhat 2008. Ecotourism Development in India: Communities, Capital and Conservation published by CEE, Ahmedabad

I. Course Title : Knowledge Management

II. Course Code : ABM 606

III. Credit Hours : 2+0

IV. Aim of the course

The objective of the course is to provide the basics of the emerging area of Knowledge Management to students. This course throws light on few important concepts as Knowledge management and Information Technology, Knowledge process, etc.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to knowledge management	1. The Knowledge Economy 2. Knowledge Management and Information Technology
2.	Future of Knowledge Management and Industry perspective	1. Knowledge process 2. Implementation of Knowledge Management:

V. Theory

Block 1: Introduction to Knowledge Management

Unit 1: The Knowledge Economy: Leveraging Knowledge, Data-Information-knowledge-Wisdom relationship, organizational knowledge, characteristics and components of organizational knowledge –Building knowledge societies- Measures for meeting the challenges of implementing, KM programmes.

Unit 2: Knowledge Management and Information Technology: Role Information Technology in Knowledge Management Systems, Knowledge Management tools, Creative effective Knowledge Management Systems through Information Technology, ERP and BPR, Data Warehousing and Data Mining.

Block 2: Future of Knowledge Management and Industry Perspective

Unit 3: Future of Knowledge Management and Industry perspective: Companies on the road to knowledge management, Knowledge Management in Manufacturing and service industry, challenges and future of Knowledge Management.

Unit 4: The Knowledge Process: Universal appeal, Stages of KM Process, Knowledge Capital vs physical capital, Customer Relationship Management, Business Ethics And KM, The Promise of Internet and the Imperatives of the new age.

Unit 5: Implementation of Knowledge Management: Discussion on Roadblocks to success, Business Intelligence and Internet platforms, web Portals, Information Architecture: A three-way Balancing Act, KM, the Indian experience, Net Banking in India. –Role of knowledge Management in Organisational Restructuring. -The Mystique of a Learning Organisation.

VI. Suggested Reading

- Mattison: *Web Warehousing and Knowledge Management*, Tata McGraw-Hill,2009
- Becerra Fernandez: *Knowledge management: An Evolutionary view*, PHI, 2009
- Fernando: *Knowledge Management*, Pearson, 2009
- B. Rathan Reddy: *Knowledge management*, Himalaya, 2009
- Tapan K Panda: *Knowledge Management*, Excel, 2009.
- Barnes: *Knowledge Management systems*, Cengage, 2009.

- Tiwana: *The Knowledge Management tool kit*, 2/e, Pearson Education, 2009.
- Warier: *Knowledge Management*, Vikas Publishing House, 2009
- Sislop: *Knowledge Management*, Oxford University Press, New Delhi, 2009
- Debowski: *Knowledge Management*, Wiley Student Edition, Wiley India, 2007

I. Course Title : Value-Chain Management in Agribusiness

II. Course Code : ABM 607

III. Credit Hours : 2+0

IV. Aim of the course

To recognize the characteristics of Global Food Systems, the multiple variables impacting Global Food Systems, to identify value chain thinking and how it differs from supply chain thinking, the characteristics of agri-food markets, what influences their supply and demand, and what sets them apart from other markets, the role played by external factors such as population and income growth, globalization, climate change, technology, and international tradein global food systems, agribusiness and value chains, to recognize the role the consumer plays in the food system, markets, and value chains

V. Theory

Unit 1: Global Food Systems and Value-Chains

Characteristics of global food systems; identify the variables impacting global food systems; identify value chain thinking and how it differs from supply chain thinking; identify the role that external factors (for example, population and income growth, globalisation, climate change, technology and international trade) play on global food systems, agribusiness and value chains; and identify the actors in, and characteristics of, value chains, demonstrated with the building of a value chain model.

Unit 2: Agribusiness Market Dynamics

Characteristics of agri-food markets, what influences their supply and demand, and what sets them apart from other markets; identify the role that external factors, such as population and income growth, globalisation, climate change, technology and international trade, play on agri-food markets; interpret the key elements of supply and demand; andrecognise the basic characteristics of supply and demand curves.

Unit 3: The Role of the Consumer

Role the consumer plays in the food system, markets and value chains; recognise the consumer characteristics, trends and behaviours that influence value chains; and recognise some of the techniques used in market and consumer researchto better understand consumer behaviour.

VI. Suggested Reading

- Acharya SS and Agarwal NL. 2011. *Agricultural marketing in India*. Oxford and IBH.
- Altekar RV. 2006. *Supply Chain Management: Concepts and Cases*. PHI
- Chopra S, Meindl P and Kalra DV. 2016. *Supply chain management: Strategy, Planning, and Operation*, Pearson Education India
- Mohanty RP. 2010. *Indian Case studies in Supply Chain Management and other Learning Resources*. Oxford.
- Chandrasekaran N. 2010. *Supply Chain Management: Process, system and Practice*. Oxford.

- Singh Sukhpal. *Organic Produce Supply Chains in India-organisation and governance*. Allied Publ.

I. Course Title : Agri Entrepreneurship and Corporate Governance

II. Course Code : ABM 608

III. Credit Hours : 1+0

IV. Aim of the course

The course aims to make students understand the nature of ntrepreneurship, and acquaint the students with challenges of starting new ventures and enable then to investigate, understand and internalize the process of setting up a business. Objective is also to enlighten them with the importance of Corporate Good Governance and Business Ethics.

The course is organized as follows:

No	Blocks	Units
1.	Agri Entrepreneurship and Feasibility Studies	1. Nature of Entrepreneurship 2. Starting the venture 3. Functional plans and Sources of finance
2.	Introduction to Business Ethics and Corporate Governance	1. Business Ethics 2. Corporate Governance

V. Theory

Block 1: Agri Entrepreneurship And Feasibility Studies

Unit I: Nature of Entrepreneurship: Concept, knowledge, skills requirement and functions; characteristic of successful entrepreneurs; ; scenario in India and Abroad, entrepreneurship process; factors impacting emergence of entrepreneurship; managerial vs. entrepreneurial approach and emergence of entrepreneurship, Risk Reduction strategies

Unit 2: Starting the venture: generating business idea – sources of new ideas, methods of generating ideas, SWOT Analysis, environmental scanning, competitor and industry analysis; feasibility study – market feasibility, technical/operational feasibility, financial feasibility; drawing business plan; preparing project report; presenting business plan to investors.

Unit 3: Functional plans: marketing plan – marketing research for the new venture, steps in preparing marketing plan, contingency planning; organizational plan – form of ownership, designing organization structure, job design, manpower planning; Financial plan – cash budget, working capital, proforma income statement, proforma cash flow, proforma balance sheet, break even analysis.

Unit 4: Sources of finance: debt or equity financing, commercial banks, venture capital; financial institutions supporting entrepreneurs, Government Grants and Subsidies, Entrepreneurship Promotion Schemes of Department of Industries (DIC), KVIC, SIDBI, NABARD, NSIC, APSFC, IFCI and IDBI etc.; legal issues – intellectual property rights patents, trademarks, copy rights, trade secrets, licensing; franching.

Block 2: Introduction To Business Ethics And Corporate Governance

Unit 5: Necessity for Business Ethics- Salient Issues in Ethics and Commerce-

Shadow Economy – Basic Principles in Ethics –Corporate Climate and corporate climate audits – Political Issues – Nature and theory of Ethics, Corporate Governance- Historical perspective and issues of Corporate Governance –Corporate Governance mechanisms – Corporate Governance Models, – The confederation of Indian Industry's initiative.; Corporate Social Responsibility

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the concept of agripreneurship and its application for starting a new venture
– Learn the basics of making functional plans like marketing, production and financial
– Acquire the knowledge about business ethics and corporate governance

VII. Suggested Reading

- Robert Hisrich Michael Peters Dean Shepherd Entrepreneurship 10th Ed 2016 by McGraw-Hill Education
- Vasanth Desai: *Entrepreneurship*, HPH, 2011.
- David Martin: *Corporate Governance*, Viva, 2010.
- Nandan H: *Fundamentals of Entrepreneurship*, PHI, 2013.
- Barringer: *Entrepreneurship*, Pearson, 2015.
- RK Mishra, Gitarani: *Corporate Governance*, Excel, 2012.
- V. Balachandran and V. Chandrasekaran: *Corporate Governance & Social Responsibility*, PHI, 2009.
- A.C. Fernando: *Business Ethics*, Pearson, 2009.
- Laura P Hartman and Abha Chatterjee: *Business Ethics*, TMH, 2009.
- Tripat Kaur: *Values and Ethics in Management*, 2/e, Paragon International, 2009.

I. Course Title : International Food and Agri Business

II. Course Code : ABM 609

III. Credit Hours : 2+0

IV. Aim of the course

The objective of the paper is to acquaint the students with the fundamentals of international business, its environment and complexities. The paper provides exposure to multiple dimensions of the field and imparts international perspective to business decisions.

The course is organized as follows:

No	Blocks	Units
1	Global trends in International trade	1. Structure of IB environment 2. Global financial system,
2	Global manufacturing and material management	1. International product life cycle, product and branding decisions; 2. Export assistance and incentives in India 3. Harmonizing accounting difference across countries 4. Ethical dilemmas and social responsibility issues

V. Theory

Block 1: Global Trends In International Trade

Unit I: Global trends in international trade and finance; dimensions and modes of IB; structure of IB environment; risk in IB; organizational structure for IB; world trading system and impact of WTO; exchange rate systems; global financial system; barriers to IB; international business information and communication.

Unit II: Foreign market entry strategies; country evaluation and selection; factors affecting foreign investment decisions; impact of FDI on home and host countries; types and motives for foreign collaboration; control mechanisms in IB.

Block 2: Global Manufacturing and Material Management

Unit I: Decisions concerning global manufacturing and material management; outsourcing factors; managing global supply chain; International product life cycle, product and branding decisions; managing distribution channels; international promotion mix and pricing decisions; counter trade practices; mechanism of international trade transactions. EXIM policy of India. Export costing and pricing, Export procedures and export documentation. Export assistance and incentives in India.

Unit II: Harmonizing accounting difference across countries; currency translation methods for consolidating financial statements; the LESSARD-LORANGE Model; cross cultural challenges in IB; international staffing decisions; compensation and performance appraisal of expatriate staff; ethical dilemmas and social responsibility issues.

I. Course Title : Communication for Management Teachers

II. Course Code : ABM 610

III. Credit Hours : 0+2

IV. Aim of the course

Communication in management education is not limited to classroom teaching. There are lot of innovative techniques to make teaching and learning interesting, practical and effective. There are various researches are done for methodological and effectiveness aspects. This course will be dealt understanding all the methods of communication for management teaching in learning by doing method and presenting the various researches done in this field.

The course is organized as follows:

No	Blocks	Units
1.	Management education	1. Action gaps in education and latest developments and required skills
2.	Theory and techniques of communication in management	1. Active listening, group communication 2. Emotional perspective in teaching 3. Learning in management education
3.	Case teaching and writing	1. Writing a case and teaching note, Critiquing a research article

VI. Theory

Block 1: Management Education

Unit 1: Management education: Action gaps in education and latest developments and required skills

Block 2: Theory and Techniques of Communication in Management

Unit 1: Communication: Active listening, group communication, Language process Presentation on readings- recorded and graded: Oral presentation & computer assisted presentations

Unit 2: Theory and techniques: Didacticism, Group work & discussion method, Simulation, facilitation skills and styles for experiential learning. Emotional perspective in teaching

Unit 3: Learning in management education: Experiential learning, Action Learning, Group learning, Simulation and games, Role Play, Teaching and learning through Electronic Media

Block 3: Case Teaching and Writing

Unit 1: Case method of teaching: Writing a case and teaching note, Critiquing a research article

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 2

Basic Sciences

- Agricultural Chemicals
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Contents

Acknowledgements

At the outset,on behalf of committee, we expresses sincere gratitude to the Dr Trilochan Mohapatra, Director General ICAR and Dr Narendra S Rathore, DDG (Edn), ICAR for providing the unique opportunity to participate in the comprehensive program of restructuring PG and Ph.D. curricula and syllabi. Our deep sense of gratitude is reserved for Dr G. Venkateswarlu, ADG (EQR) and Dr K.L. Khurana, principal scientist and coordinator of BSMA committees, ICAR for their costant help and encouragement during the entire period of activity of the BSMAC Basic Sciences.

The euphoria that accompanies successful completion of any task would be incomplete without expression of appreciation of simple certitude to the people who actually made it possible to achieve the goal through their active participation and painstaking efforts. Weare thankful to the subject expert members of this BSMA committee, Dr Suresh Walia from IARI, Dr Samindra Baishya and Dr Kaushik Das from Assam Agricultural University and Dr Nafisa Ali from MPUA&T, Udaipur for owning the challenge of design and development of restructured syllabi of their respective disciplines. This is worth mentioning that inspite of several constraints, all the members did highly commendable task in a consistent and timebound fashion.

We take proud privilege to express our regards and gratitudes to Dr M.L. Lodha, Dr Shelly Pravin, Prof. M. Udaykumar, Dr D.C. Uprety, Dr C Viswanathan, Dr Shashibala Singh, Dr S.K. Guru, Dr A. Amaregouda, Dr Uday Burman, Dr T. Girija, Dr K.K. Barua, Dr Nirmali Gogoi, Dr S.B. Bhamburdekar, Dr Renu Pandey, Dr Ajay Arora, Dr Vijay Paul, Dr S. Leksmy, Dr Anjali Anand and Dr B. Bharalifor their constructive inputs.

We, humblyplace on record our heartfelt thanks tonational subject experts, resource persons, colleagues and friends from the scientific community, viz. Dr B. Mohanraju, Dr Sheshshayee M.S., Dr N. Nataraja Karaba,Dr Geeta Shirnalli, Dr S. Rame Gowda, Dr M.K. Prasanna Kumar, Dr Geetha Govind, Dr K.S. Shiv Shankar, Dr H. Laxman from UAS & IIHR, Bengaluru; Dr Lekshmi. S., Dr Madan Pal Singh, Dr Renu Pandey, Dr Vijay Paul, Dr Ajay Arora, Dr Shivani Nagar, Dr Ashish Ranjan,Dr Irani Mukherjee, Dr A.K. Dikshit, Dr A. Tyagi andDr A. Dahuja, Dr Sunil Pabbi, Dr Lata, Dr (Ms.) Archna Suman, Dr Neera Singh, Dr M. Senthil Kumar, Dr Archana Sachdev, Dr Suman Gupta, Dr SupradipSaha, Dr Neethu Narayanan, Dr Indu Chopra, Dr Aditi Kundu, Dr V. S. Rana, Dr Jitender Giri from IARI & NIPGR, New Delhi; Dr P. Seekanth Bhogadi, Dr K. Jayalalitha, Dr V. Umamaheash, Dr P. Sudhakar and Eswarayya Rami reddy from ANGRAU & IISER, Tirupati; Dr P. Boominathan, Dr Roy Stephan, Dr D. Uma, Dr N.O. Gopal, Dr T. Kalaiselvi, Dr V. Krishnapriya, Dr Vijayalakshmi, Dr M. Geetha Prakash from TNAU, KAU, SBI and Annamalai University; Dr B. Hebbar, Dr M. Mamrutha, Dr Ishwar Singh, Dr James Jacob, Dr A. Dutta, Dr P.S. Basu, Dr Harsh Nayar from CPCRI, IIWBR, IIMR, IIPR, RRII, and Punjab University; Dr J. Kumar, Director, IPFT, Gurugram, Haryana, Dr Nutan Kaushik, Director, Amity University, Noida; Dr A. Dubey and Dr R.M. Naik, GBPUAT, Prof. Ashim Chowdhury, Emeritus Fellow, Calcutta University, Dr G.K. Pandit and Dr Somnath Pal, UBKV, Dr (Mrs) J. Dutta, Prof. S. Pal, Prof. Anjan Pal, Dr Subhasis Mondal and Prof. R.K. Kole from BCKV, Dr N.K. Gupta, SKNAU, Dr L.K. Chug, HAU, Dr Avijit Das, Principal Scientist, NINFET, Tollygunge, Kolkata and Dr Pratik Satya, Principal Scientist, CRIJAF, Barrackpore, West Bengal.

Thanks are also due to valuable contribution and support extended by SPCW, Kottayam; ICAR-CIAE, Bhopal; ICAR-NRRI, Cuttack; CSKHPKV, Palampur, HP; BAU, Ranchi; SPRERI, VV Nagar; PAU, Ludhiana; CCSHAU, Hisar; TNAU, Coimbatore; RAU, Bikaner; AAU, Anand; Banaras Hindu University and Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur representatives of Rallis India Ltd, Bangalore, UPL Ltd, Mumbai and Sumitomo Chemicals, New Delhi.

Our heartfelt special thanks are also due to a bunch of our affectionate and diligent colleagues as well as members of the local organizing Committee Dr Tirthankar Banerjee, Dr Anirban Dutta, Dr Prashant Kaushik, Dr Suman Manna, and Dr Neeraj Patanjali, IARI, without whose active participation and generous help during National workshop, the present work could not be completed.

Finally we extend our thanks to one and all who have contributed even in a small way by giving suggestions, observations, views etc. to help and enrich us to complete our assignment.

Dr Anupama Singh
Dr Amitava Bhattacharya
Agricultural Chemicals

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Agricultural Chemicals

Preamble
(Agricultural Chemicals)

Agricultural chemicals, generally referred to as pesticides, play a vital role in sustaining agriculture productivity by controlling insect pests and diseases that damage field crops and food commodities during cultivation, transport and storage. In addition, they stimulate plant growth, enhance agri-input (water and fertilizer-N use) efficiency to increase farm productivity, and control pests of veterinary and public health importance. The Discipline of Agricultural Chemicals is multidisciplinary as it is linked to various agricultural and basic science disciplines like Entomology, Plant Pathology, Nematology, Toxicology, Weed Science, Environmental Science, Chemistry, Biochemistry, Microbiology, and Soil Sciences & Agricultural Chemistry. Due to the excessive use/ misuse of inherently toxic pesticides, environmental scientists and ecologists from time to time raise concerns about theirharmful effects on humans, domestic animals and the environment. However, since benefits outweigh risks,agricultural chemicals will continue to play a leading role in crop protection.

The world is witnessing huge scientific, technological, digital and socio-economical transformation necessitating nations to launch new initiatives for their development and growth. With emphasis on the holistic education, the new National Education Policy (NEP) declared by the Government of India is aimed at bringing about sea changes in higher education. It will not only transform India into a global knowledge superpower, but will also help it achieve United Nations Sustainable Development Goal-4 aimed at ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all.

Global warming and climate change has posed significant challenges to food security. Changes in crop-pest and host-pathogen complexions haveresulted in minor pests becoming major, and have increased the instances of pest resurgence and resistance development in insect pests and pathogens. In last ten years significant advances have been made globally in the field of crop protection and agricultural chemicals in particular. New molecules with novel chemistries and modes of actions are being developed and registered globally. With change in focus from pest kill to pest control, old generation highly toxic and persistent pesticides are being replaced with new generation reduced risk pesticides with novel chemistries and modes of action. These developments have necessitated restructuring of the course curriculum of the Discipline of Agricultural Chemicals at the Master's and Doctoral level to enable students undertake research in the emerging areas of agrochemical R & D, formulation technology, as well as foodand environment safety through chemical, biochemical, biotechnological and nano-technological interventions. The in-depth understanding of the subject will empower students, researchers, farmers and other stakeholders to take informed decisions about safe use of pesticides in crop and environment protection

In the discipline of Agricultural Chemicals, 20 post-graduate courses have been comprehensively restructured after modification of the existing courses. Of these, 12 are M.Sc. and 8 are Ph.D. courses. Course numbered AC-503,AC-504, AC-505, AC-506, and AC-510 (15 credits) will be compulsory for the M. Sc. students, and the courses numbered

AC-601 and AC-602 (7 credits) will be compulsory for the Ph.D. students. The coursenumbered AC-501 and AC-502 have been designed for students from outside the discipline, and courses AC-503, AC-504, AC-505 and AC-602 may be joint interdisciplinary courses. The doctoral degree level courses (AC-601 to AC-605) are advanced and research oriented.

Basic Chemistry (AC-503) course has been consolidated after clubbing Basic Chemistry I and II courses and modifying/ updating the entire course content. Natural Product Chemistry (AC-504) course has been designed as a new course with more emphasis on metabolomics, health-benefitting nutraceuticals,phytoceuticals,natural antioxidants and food colorants, polymers, enzymes and other natural products for industrial and other applications. The course on Agrochemical Regulation, Quality Control and Management (AC-505) and Pesticide Residue Chemistry (AC-510) have been completely revamped by incorporating provisions of Food Safety and Standards Act 2006 and Rules 2011, Pesticide Management Bill (2017), ecological and consumer risk assessment, and MRL fixation as per the national/ international guidelines. In view of the recent advancements, new topics on acaricides, termiticides, management of resistance in insects, fungi and weeds, NABL accreditation of *laboratories,* and national/international guidelines on good agricultural practices (GAP), and good laboratory practices (GLP) have been added in the revised syllabus. New crop protection concepts like development and use of entomopathogenic nematodes, entomopathogenic fungi, plant inhabited fungal endophytes, nanotechnology, biotechnologyand plant incorporated protectants have also been introduced in the revised syllabus,

Practical content in the designed courses requires modern equipment for extraction, separations, chemical characterization, structure determination, synthesis, and analysis of pesticide residues in food commodities and in soil and aquatic environment. For better research and teaching capabilities, obsolete equipment(s) need to be replaced with new ones like GLC, HPLC, GC-MS-MS, LC-MS-MS, particle size analyzers etc. Additional funds may be required for purchasing such equipment and their spare parts and supplies. Thus, a one-time grant of Rs. 5 crores with a recurring contingency of Rs. 20 lacs per annum will be needed to effectively run Master's and Doctoral programmes in ICAR-IARI/SAUs where the courses of Agricultural Chemicals are taught.

Course Title with Credit Load
M.Sc. (Ag) in Agricultural Chemicals

Course Code	Course Title	Credit Hours
AC 501	Introduction to Agrochemicals	2+0
AC 502	Chemical Laboratory Techniques	1+2
AC 503*	Basic Chemistry	3+1
AC 504*	Natural Product Chemistry	2+1
AC 505*	Agrochemical Regulation, Quality Control and Management	2+0
AC 506*	Agrochemicals for Insect Mite and Termite Management	2+1
AC 507	Agrochemicals for Disease Management	2+1
AC 508	Agrochemicals for Weed and Crop Management	2+1
AC 509	Chromatographic and Spectroscopic Techniques	2+1
AC 510*	Pesticide Residue Chemistry	2+1
AC 591	Master's Seminar	1+0
AC 599	Master's Research	30

*Core courses

Course Contents
M.Sc. (Ag) in Agricultural Chemicals

I. Course Title : Introduction to Agrochemicals
II. Course Code : AC 501
III. Credit Hours : 2+0

IV. Why this Course?

Pesticides and allied agrochemicals are required for the management of pests of agriculture, veterinary and public health importance. Since pesticides are inherently toxic, their excessive use has led to the residues detrimental to human health and the environment. This interdisciplinary course provides introductory knowledge to students about the use of crop protection chemicals in pest control.

V. Aim of the Course

To provide basic information about crop protection chemicals, their production/ consumption and trade statistics, and adverse impact of these chemicals on human health and the environment.

The course is organized as follows:

No.	Blocks	Units
1.	Agrochemical use and Trade Statistics	1. Agrochemicals and Pest Management 2. Pesticide Production, Consumption and Trade Statistics
2.	Different Group Pesticides	1. Botanical and Biopesticides 2. Synthetic Pesticides
3.	Pesticides Formulation	1. Solid and Liquid Formulations 2. Role of Adjuvants in Pesticide Formulations
4.	Pesticide Residues, their Adverse Effects and Safe Disposal	1. Pesticide Residues in Food and the Environment 2. Adverse Effect of Pesticides on Non-target Organisms 3. Safe Disposal of Pesticides

VI. Theory

Block 1: Agrochemicals and Trade Statistics

Unit 1: Agrochemicals and Pest Management

Definition of pests and pesticides, Synthetic and natural plant protection chemicals – history and classification, House-hold pesticides, Non-pesticidal agrochemicals like nitrification inhibitors, chemical hybridizing agents, hydrogels, soil conditioners, and plant growth stimulants, Pesticide toxicity ($LD_{50,}$ $LD_{90,}$ LC_{50}, EC_{50}, I_{50}),Pesticide antidotes. Safety precautions in pesticide application, Introduction to integrated pest management (IPM).

Unit 2: Pesticide Production, Consumption and Trade Statistics

Pesticide production and consumption in India and other countries, Pesticide export and import

Block 2: Pesticide Groups

Unit 1: Botanical and Biopesticides

History of botanical and biopesticide use, Structure, properties, and use of conventional botanical insecticides - nicotine, pyrethrins, rotenones and neem limonoids. Plant allelochemicals, Biopesticides and bioagents.

Unit 2: Synthetic Pesticides

History of synthetic pesticide use, Structure, properties, and uses of insecticides-organochlorines, organophosphates, carbamates, synthetic pyrethroids, fungicides (inorganic and organic), nematicides, rodenticides, herbicides, and plant growth regulators (PGR)

Block 3: Pesticide Formulation

Unit 1: Solid and Liquid Formulations

Formulation of pesticides- objective and classification, Conventional solid and liquid formulations such as EC, WP, Dust, Granule etc. Physico-chemical properties of formulations

Unit 2: Role of Adjuvants in Pesticide Formulations

Pesticide adjuvants like synergists, stabilizers and surfactants, Pesticide carriers and diluents General methods of preparation of solid and liquid formulations

Block 4: Pesticide Residues, Their Adverse Effects And Safe Disposal

Unit 1: Pesticide Residues in Food and the Environment

Pesticide residue - definition and significance, Pesticide residues in food commodities and in water, air and in soil environment

Unit 2: Adverse Effect of Pesticides on Non-target Organisms

Adverse effect of pesticides on human health, soil health, and on non-target organisms

Unit 3: Safe Disposal of Pesticides

Various techniques for disposal of unused, obsolete, and expired pesticides and their solid and liquid formulations, Disposal of pesticide containers

VII. Teaching methods/activities

– Lectures assignments
– Review of research documents and its presentation
– Periodical quizzes
– Mid-term and final examination

VIII. Learning outcome

After successful completion of the course, student will acquire basic knowledge about agrochemicals, their formulations and safe use in crop protection. Student will also know about the adverse effects of pesticides and ways to dispose obsolete, expired and unused pesticides and pesticide containers/packaging

IX. Suggsted Reading

- DC Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Marrs TC & Bryan BT. (Eds.). 2004. *Pesticide Toxicology and International Regulation*. John Wiley & Sons.
- Parmar BS and Tomar SS. 2004. *Pesticide Formulation Theory and Practice*, CBS Publishers & Distributors-New Delhi, ISBN: 9788123911243, 8123911246
- Tomar SS and Parmar BS. 1992. *Dictionary of Agricultural Chemicals*. Academic India Publ.
- Handa SK 2004. *Principles of Pesticide Chemistry*. Publisher Agrobios (India), Jodhpur (ISBN 10: 8177542168 ISBN 13: 9788177542165)
- Pimentel D. *Encyclopedia of Pest Management* (1st Edition), CRC Press, 931 pp. ISBN 9780824706326.
- Pimentel and Lehman H (Eds.). 1993. The Pesticide Question, Environment, Economics and Ethics, pp442.DOI 10.1007/b102353, Springer US.
- Hassall KA. 2013. *The Chemistry of pesticides, their metabolism, mode of action and uses in Crop Protection* (ISBN: 9789386237118, 9386237113) Scientific Publishers India, pp 372.
- FICCI-TSMG (2016). *Next Generation Indian Agriculture: Role of Crop Protection Solution, A report on Indian Agrochemical Industry*. pp 45.

I. Course Title : Chemical Laboratory Techniques

II. Course Code : AC 502

III. Credit Hours : 1+2

IV. Why this Course?

Students desirous of pursuing research in agrochemicals and crop protectionare expected to know about the safe handling of laboratory chemicals and instruments. They need to be well versed with extraction, purification and separation techniques commonly employed in a chemical laboratory.

V. Aim of the Course

To acquaint students with laboratory hygiene, upkeep and maintenance of laboratory, handling of chemicals/solvents/glassware, as well as distillation and chromatographic techniques:

No.	Blocks	Units
1.	Laboratory Hygiene and Safe Laboratory Practices	1. Safe Storage and Handling of Chemicals 2. Safety Practices in Chemical Laboratory
2.	Distillation, Extraction and Separation Techniques	1. Theory and Practice of Distillation and Drying of Solvents 2. Theory and Practice of Extraction and Other Techniques 3. Theory and Practice of Chromatographic Techniques

VI. Theory

Block 1: Laboratory Hygiene and Safe Laboratory Practices

Unit 1: Safe Storage and Handling of Chemicals

Laboratory hygiene and safety, Handling and storage of hazardous (flammable, volatile, and corrosive) chemicals, Accurate weighing of chemicals, Maintenance of lab-wares, Maintenance of lab notebooks and records of laboratory chemicals/solvents

Unit 2: Safety Practices in Chemical Laboratory

Precautions while carrying out lab experiments, Use of safety gadgets, Safe disposal of reaction wastes and used solvents, Laboratory accidents and their management

Block 2: Distillation, Extractionand Separation Techniques

Unit 1: Theory and Practice of Distillation and Drying of Solvents

Solvent distillation, Fractional distillation, Steam distillation, Hydro-distillation, Drying of solvents,

Unit 2: Theory and Practice of Extraction and Other Techniques

Different extraction techniques, Cold extraction, Soxhlet extraction, liquid-liquid partitioning, Crystallization and sublimation, Determination of melting point, boiling point, and density of organic compounds

Unit 3: Theory and Practice of Chromatographic Techniques

Chromatography - principle and practice, Partition and adsorption chromatography (TLC, Preparative TLC, HPTLC, Paper chromatography, Column chromatography), Chromatography solvents and chromogenic reagents.

VII. Practicals

- Simple distillation, vacuum distillation, and fractional distillation of solvents/ volatile materials (e.g. essential oils)
- Determination of melting point, boiling point, density, etc.
- Purification and drying of organic solvents
- Crystallization and sublimation techniques.
- Solvent extraction techniques (cold extraction, Soxhlet extraction, percolation, accelerated solvent extraction), and refluxing a reaction
- Chromatographic separation of organic compounds by paper chromatography and thin layer chromatography (TLC)
- Separation of compounds by preparative TLC, HP-TLC and column chromatography

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge aboutsafe handling of chemicals, lab safety and basic laboratory techniques

X. Suggested Reading

- Fessenden RJ, Fessenden JS, Feist P. 2001. *Organic Laboratory Techniques* 3rd Edition, Publisher: Cengage Learning, 256 pages
- Feist P. 2002. *Handbook for Organic Chemistry Lab*. 6th Ed. Brooks/Cole
- Vogel AI. 1996. *Vogel's Textbook of Practical Organic Chemistry*. 5th Ed. Prentice Hall.
- Pavia DL, Kriz GS, Engel UJF. 2006. *Organic Chemistry: A Lab Manual*, Thomson and Brooks/Cole 972 pages.
- Brown SL. 2012. *Laboratory Techniques for General Chemistry*, Hayden McNeil; 208 pages
- ICAR Institute/SAU, *Practical Manual on Chemical Laboratory Techniques*

I. Course Title : Basic Chemistry

II. Course Code : AC 503*

III. Credit Hours : 3+1

IV. Why this Course?

Basic knowledge of physical, inorganic and organic chemistry is fundamental for understanding various aspects of pesticides and allied agrochemicals, pesticide residue analysis, and dynamics in the environment. This course empower the students with important aspects of chemistry.

V. Aim of the Course

To acquaint the students about the basics of inorganic, physical and organic chemistry

The course is organized as follows:

No.	Blocks	Units
1.	Basics of Inorganic Chemistry	1. Properties of Atoms, Molecules And Basic Elements 2. Chemical Bonding and Electronic Effects
2.	Basics of Physical Chemistry	1. Chemical Kinetics 2. Chemical Thermodynamics 3. Surface Chemistry 4. Solution and Electrochemistry
3.	Basics of Organic Chemistry	1. Reactive Intermediates in Chemical Reactions 2. Introduction to Stereochemistry 3. Chemistry of Aliphatic and Aromatic Compounds 4. Chemistry of Heterocyclic Compounds

VI. Theory

Block 1: Basics of Inorganic Chemistry

Unit 1: Properties of Atoms, Molecules and Basic Elements

Modern periodic law and periodic table, Properties of atoms, molecules and basic elements like C, H, O, S, and N, Atmospheric pollutants (oxides of C, N, and S), Atomic and ionic radii, Oxidation states and chemical reactivity, Acid-base chemistry, Introduction to organometallic and coordinated compounds

Unit 2: Chemical Bonding and Electronic effects

Nature of chemical bonding, hydrogen bonding, Van der Waals forces, Inductive effect, electromeric effect, Resonance effect, Hyperconjugation, Electronegativity and Dipole moment

Block 2: Basics of Physical Chemistry

Unit 1: Chemical Kinetics

Kinetic theory of gases, Collision theory, Maxwell - Boltzmann distribution law, Order and molecularity of reactions, First order and second order reactions, Effect of concentration, temperature, pressure and catalyst on rate of reaction, Arrhenius equation, Enzyme kinetics, Catalysis.

Unit 2: Chemical Thermodynamics

First law of thermodynamics, concept of work, internal energy and enthalpy, Second law of thermodynamics, entropy and free energy, Third law of thermodynamics

Unit 3: Surface Chemistry

Introduction to surface chemistry, Adsorption, physi-sorption, and chemisorption, Factors affecting adsorption of gases on solids- Freundlich and Langmuir adsorption isotherm

Unit 4: Solution and Electrochemistry

Colligative properties of solutions, law of mass action, Ionic equilibria in solutions, Phase rule and its application to one- and two- component systems, Hydrolysis, Solubility product, pH and buffer solutions, True solutions, colloid and suspensions, Electrochemistry, Redox reactions, Potentiometric analyses, Conductance in electrolytic solutions, Laws of electrolysis, Nernst equation, Metal corrosion

Block 3: Basics of Organic Chemistry

Unit 1: Reactive Intermediates in Chemical Reactions

Carbenes, carbanions, carbonium ion, free radicals and their role in organic reactions

Unit 2: Introduction to Stereochemistry

Chirality and optical isomerism, Geometric isomerism, Designation of configuration (D-L and R-S system), Conformations of acyclic and cyclic systems

Unit 3: Chemistry of Aliphatic and Aromatic Compounds

Preparation, properties and uses of some important aliphatic, alicyclic and aromatic compounds (halogenated, nitro, amino-compounds, diazonium salts, aromatic sulphonic acids, phenols, quinones and aromatic acids, naphthalene and naphthaquinone).

Unit 4: Chemistry of Heterocyclic Compounds

Preparation, properties and uses of some important heterocyclic compounds (furan, thiophene, pyrrole, pyrazole, imidazole, oxazole, thiazole, pyridine, piperidine, quinnoline, isoquinnoline etc.)

VII. Practicals

- Micro-weighing of compounds and preparation of different concentration of solutions Preparation of different pH solutions and buffer solutions
- Detection of elements (C, H, O, N, S Halogens) in organic compounds
- Detection of functional groups
- Experiments to demonstrate adsorption of a chemical on solid substrate
- Separation and identification of organic compounds in binary mixtures.
- Rate kinetics and Colligative properties.

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the fundamental aspects and concepts of basic chemistry

X. Suggested Reading

- Eliel EL and Wilen SH. 1994. *Stereochemistry of Organic Compounds*. Wiley-Interscience.
- Finar IL. 1989. *Organic Chemistry*. Vols. I, II. Longmans.
- Hendrickson JB, Cram DJ and Hammond GS. 1970. *Organic Chemistry*. McGraw-Hill.
- Morrison RT and Boyd RN. 1992. *Organic Chemistry*. 6th Ed. Prentice Hall.
- Vogel AI, Tatchell AR, Furnis BS and Hannaford AJ. 1996. *Vogel Textbook of Practical Organic Chemistry*. Forestmillbooks,UK.
- Negi AS and Anand SC. 2003. *A Text Book of Physical Chemistry*. Wiley Eastern.
- Moore WJ. 1987. *Basic Physical Chemistry*. Prentice Hall of India
- Alberty RA and Silbey RJ. 1996. *Physical Chemistry*. 2nd Ed. John Wiley & Sons.
- Moore WJ. 1987. *Basic Physical Chemistry*. Prentice Hall of India
- ICAR Institute/SAU *Practical Manual on Basic Chemistry*

I. Course Title : Natural Product Chemistry

II. Course code : AC 504*

III. Credit Hours : 2+1

IV. Why this Course?

Natural Product Chemistry course is useful to multidisciplinary students of chemistry, agricultural chemicals, entomology, pathology, and biochemistry. The course is designed to improve the student's understanding of bioactive natural products and their role in human welfare.

V. Aim of the Course

To apprise the students about the extraction, purification, and characterization of bioactive natural products and their use in human health, medicines and agriculture The course is organized as follows:

No.	Blocks	Units
1.	Natural Products: Chemistry and Uses	1. Chemistry and Uses of Fats, Lipids, Terpenoids, and Carotenoids 2. Chemistry and Uses f Alkaloids, Flavonoids, Steroids, and Triterpenoids 3. Chemistry and Uses of Carbohydrates, Amino Acids, Proteins, and Nucleic Acids 4. Introduction to Metabolomics
2.	Natural Antioxidants and Food Colorants from Food and Non-Food Sources	1. Natural Antioxidants and Food Colorants from Food Crops 2. Nutraceuticals and Phytoceuticals from Non-Food Sources
3.	Natural Polymers And Enzymes	1. Natural Polymers and their Application 2. Enzymes and Their Industrial Applications

VI. Theory

Block 1: Natural Products: Chemistry and Uses

Unit 1: Chemistry of Fats, Lipids, Terpenoids, and Carotenoid

Introduction to natural products, Structure, chemistry, properties and function of fats, lipids, terpenoids, and carotenoid group of natural products

Unit 2: Chemistry of Alkaloids, Flavonoids, Steroids, and Triterpenoids

Structure, chemistry, properties and function alkaloids (berberine, morphine, caffeine, atropine), flavonoids (Luteolin, quercetin, catechin, naringin, anthocyanins, theaflavins) and phenolic acids (benzoic acid and cinnamic acid derivatives), steroids (cholesterol, cortisone, testosterone, progesterone), and saponin (steroidal, triterpenic and steroid-alkaloidal) group of natural products.

Unit 3: Chemistry of Carbohydrates, Amino Acids, Proteins, and Nucleic Acids

Structure, chemistry, properties and function of carbohydrates, amino acids, proteins, and nucleic acids

Unit 4: Introduction to Metabolomics

Definition, Plant and microbial metabolomics, Metabolome analysis (profiling of secondary metabolites) by GC-MS, LC-MS and NMR spectrometery, Application of metabolomics in different fields

Block 2: Natural Antioxidants and Food Colorants From Food and Non-food Sources

Unit 1: Natural Antioxidants and Food Colorants from Food Crops

Natural oxidants and their mode of action, Different types of natural oxidants from vegetable, fruit and cereal crops (Examples: carotene, lycopene, betanaine, capsanthins, capsicinoids, anthocyanins, curcuminoids etc.)

Unit 2: Nutraceuticals and Phytoceuticals from Non-Food Sources

Nutraceuticals and phytoceuticals from microalgae (e.g. phycocyanins), seabuckthorn (phenolics and flavonoids), medicinal plants (boswellic acid, artemisinin, andrographinolides, withanolides, taxol, forskolinetc.) and marine products

Block 3: Natural Polymers and Enzymes

Unit 1: Natural Polymers and their Application

Different types of natural polymers, Chemistry of natural polymers (Starch, cellulose, Agar, inulin, chitosan, alginate, dextran, guar gum, gum Arabic, gum tragacanthin, xanthan gum, pectin, psyllium etc.). Application of polymers in agrochemical, food and other industries

Unit 2: Enzymes and their Industrial Application

Major classes of enzymes, Enzymes in food industry, industrial enzymes and their application in pharma, leather, textile, detergent and other industries

VII. Practicals

- Extraction of essential oil from mint leaves, lemon and orange peel etc.
- Extraction and purification of bioactive natural products like lycopene, from tomato or watermelon
- Extraction and purification of curcuminoids from turmeric rhizome
- Extraction and purification of anthocyanins from black carrot, purple cabbage, grapes or jamun etc
- Extraction and purification of bioactive natural products namely capsanthin and capsaicinoids from chili/paprika.

• Identification and characterization of the phytochemicals by GC-MS/LC-MS

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the bioactive natural products and their use in medicines, crop protection and other industrial applications

X. Suggested Reading

- Thomson RH (Ed). 1993. *The Chemistry of Natural Products*, DOI 10.1007/978-94-011-2144-6, Springer Netherlands, 453 pages
- Sujata V. Bhat, B.A. Nagasampagi, Meenakshi Sivakumar. 2005. *Chemistry of Natural Products* Springer Science & Business Media, 840 pages
- Rensheng Xu, Yang Ye, Weimin Zhao. 2011. *Introduction to Natural Products Chemistry*, CRC Press, 381 Pages
- Bernd Schaefer. 2014. *Natural Products in the Chemical Industry*, Springer-Verlag Berlin Heidelberg, 831 pages.
- Talapatra SK and Talapatra B. 2015. Chemistry of Plant Natural Products, Springer-Verlag Berlin Heidelberg, 1180 pages
- ICAR Institute/SAU. *Practical Manual on Natural Product Chemistry*

I. Course Title : Agrochemical Regulation, Quality Control and Management

II. Course Code : AC 505*

III. Credit Hours : 2+0

IV. Why this course?

Agricultural chemicals being inherently toxic need to be handled with caution during their production, transport, storage, usage and disposal. The national and international regulations and guidelines ensure their safe distribution and use. Students need to be aware of such regulations and guidelines

V. Aim of the course

To acquaint students about the provisions of Insecticide Act 1968, Food Safety and Standard Act 2006, pesticide registration process, and guidelines for their safe use. The course is organized as follows:

No.	Blocks	Units
1.	Pesticide Regulation and Food Safety	1. The Insecticides Act (1968) and Rules (1971) 2. Food Safety and Standard Act (2006) & Rules (2011) 3. Pesticide Registration in India
2.	National/ International Guidelines for Safe Use of Pesticides	1. Good Agricultural Practices (GAP) and Good Laboratory Practices (GLP)

No.	Blocks	Units
		2. International Guidelines for Safe Use of Pesticides
3.	Quality Control, Quality Assurance and Accreditation	1. Quality *Assurance* and *Quality Control* in Pesticide Analysis 2. Accreditation of *Laboratories*

VI. Theory

Block 1: Pesticide Registration in India

Unit 1: The Insecticides Act (1968) and Rules (1971)

Provisions of the Insecticides Act 1968 and Insecticides Rules 1971, Schedule of the Insecticide Act. Directorate of Plant Protection, Quarantine & Storage (DPPQ&S), Central Insecticide Board and Registration Committee (CIB&RC),Guidelines for production and use of pesticides

Unit 2: Food Safety and Standard Act (2006) & Rules (2011)

Provisions of the Food Safety and Standard Act (2006) & rules (2011), Acts relating to protection of air, water and the general environment

Unit 3: Pesticide Registration in India

Requirement of data (Chemistry, Bioefficacy, Residue, Toxicology, Packaging etc) for pesticide registration in the country, Guidelines for pesticide export and import**,** Current status of registered, restricted, and banned pesticides in India

Block 2: National/ International Guidelines for Safe Use of Pesticides

Unit 1: Good Agricultural Practices (GAP) and Good Laboratory Practices (GLP)

Definition of GAP and GLP, National and international guidelines for GAP, and GLP.

Unit-2: International Guidelines for Safe Use of Pesticides

WHO/FAO Joint Meeting on Pesticide Residues (JMPR), Codex Alimentarius Commission (CAC) EU and EPA guidelines for food safety, Sanitary and phytosanitary (SPS) measures and food safety

Block 3: Quality Control, Quality Assurance and Accreditation

Unit 1: Quality Assurance and Quality Control in Pesticide Analysis

Spurious/ fake pesticides and pesticide formulations, Quality Assurance (QA) and Quality Control (QC) Quality control procedures for pesticide residue analysis, Problems related to pesticide residue analysis in a regulatory laboratory.

Unit 2: Accreditation of Laboratories

Accreditation and its importance, General criteria for accreditation of chemical and food laboratories, Introduction to ISO/IEC 17025. NABL and GLP compliance of laboratories, Role of International Laboratory Accreditation Cooperation (ILAC) and Asia Pacific Laboratory Accreditation Cooperation (APLAC) in promoting accreditation recognition arrangements (MRAs) and practices

VII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

VIII. Learning outcome

After successful completion of the course, student will acquire knowledge about the agrochemical regulation, quality control, management, and need for accreditation of chemical laboratory as per ISO/IEC 17025

IX. Suggested Reading

- EU.http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=pesticide.residue.CurentMRL&language=EN&pestResidueID=69.
- Pest Management Regulatory Agency Canada. 21 May 2014. ISSN: 1925-0843 (PDF version), Catalogue number: H113-24/2014-25E-PDF. Cucurbit vegetables (Crop group 9). http://www.hc-sc.gc.ca/cps-spc/pest/part/consultations/_pmrl2014-25/pmrl2014-25-eng.php.
- OECD (Organization for Economic Co-operation and Development), 2011. *OECD MRL calculator: spreadsheet for single data set and spreadsheet for multiple data set*, 2 March 2011. In: Pesticide Publications/Publications on Pesticide Residues. http://www.oecd.org.
- SANTE. 2017. *Guidance document on analytical quality control and validation procedures for pesticide residues analysis in food and feed.* European Commission Health and Consumer Protection Directorate–General. SANTE/11813/2017 Supersedes SANCO/11945/2015.
- USEPA (2016). https://www.epa.gov/sites/production/files/2016-03/documents/flubendiamide_ noic_published_03-04-16.pdf. (accessed 18 May 2016).
- USEPA 2016 United States Environmental Protection Agency https://www.epa.gov/sites / production/files/2016-03/documents/flubendiamide_noic_published_03-04-16.pdf.
- Gnther Voss, Gerardo Ramos &GüNther Voss. 2003. *Chemistry of Crop Protection: Progress and Prospects in Science and Regulation*. Wiley-vch Verlag Gmbh.

I. Course Title : Agrochemicals for Insect, Mite and Termite Management

II. Course Code : AC 506*

III. Credit Hours : 2+1

IV. Why this course?

Insect pests, mites and termites are the major destroyer of the agricultural crops, food commodities as well as buildings and wooden structures. Since synthetic insecticides are used to control such pests, students must learn about the chemistry, mode of action and safe use of such pest control chemicals

V. Aim of the course

To understandchemistry, synthesis, mode of action, and use of insecticides, acaricides and termiticides in agriculture and protection of buildings and wooden structures. The course is organized as follows:

No.	Blocks	Units
1.	Organochlorine, Carbamate and Organophosphorus Group Insecticides	1. Chemistry and Use of Organochlorine Insecticides 2. Chemistry and Use of Carbamate Insecticides

No.	Blocks	Units
		3. Chemistry and Use of Organophosphorus Insecticides
2.	Synthetic Pyrethroid and Neonicotinoid Group Insecticides	1. Chemistry and Use of Synthetic Pyrethroid Insecticides 2. Chemistry and Use of Neonicotinoid Insecticides
3.	Acaricides, Termiticides, Insect Growth Regulators and Newly Discovered Insecticidal Molecules	1. Chemistry and Use of Acaricides 2. Chemistry and Use of Termiticides 3. Chemistry and Use of IGRs and Newly Discovered Insecticidal Molecules
4.	Insecticide resistance	1. Insecticide Resistance and its Management

VI. Theory

Block 1: Organochlorine, Carbamate and Organophosphorus Insecticides

Unit 1: Chemistry and Use Of Organochlorine Insecticides

Introduction and classification of synthetic insecticides, Chemistry, use and mode of action of some important conventional organochlorine and cyclodiene insecticides, Present status of organochlorine pesticides

Unit 2: Chemistry and Use of Carbamate Insecticides

Chemistry, use, and mode of action of carbamate insecticides, Present status of carbamate pesticides

Unit 3: Chemistry and Use of Organophosphorus Insecticides

Chemistry, use and mode of action of some important organophosphorus insecticides. Important reactions namely Michaelis- Arbuzov reaction, Perkow reaction, Thiono-thiolo rearrangement. Present status of OP pesticides

Block 2: Synthetic Pyrethroid and Neonicotenoid Insecticides

Unit 1: Chemistry and Use of Synthetic Pyrethroid Insecticides

History and evolution of synthetic pyrethroid insecticides, Synthesis, properties, structure activity relationships, and mode of action of some important ester and non-ester synthetic pyrethroids. Current status of synthetic pyrethroids insecticides

Unit 2: Chemistry and Use of Neonicotinoid Insecticides

Neonicotinoids: Chemistry, classification, mode of action and uses, Preparation, properties anduses of some important neonicotinoids, Current status of neonicotinid insecticides

Block 3: Acaricides, Termiticides, Insect Growth Regulatorsand Newly Discovered Insecticidal Molecules

Unit 1: Chemistry and Use of Acaricides

Chemistry, classification, mode of action of some important acaricidal molecules.

Unit 2: Chemistry and Use of Termiticides

Termites of different types infesting crops and building materials, Chemistry, mode of action and uses of some important termiticides

Unit 3: Chemistry and Use of Igrs and Newly Discovered Insecticidal Molecules

Chemistry of insect growth regulators: Juvenile hormone mimics, anti-JH, Chitin synthesis inhibitors. Chemosterilants, Mode of action of IGRs, Endocrine disruptor compounds, Chemistry of newly discovered insecticidal molecules

Block 4: Insecticde Resistance

Unit 1: Insecticide Resistance and its Management

Definition, types and mechanism of insecticide resistance, Insecticide Resistance Action Committee (IRAC) guidelines for resistance management, Status of resistance to neo-nicotinoid, synthetic pyrethroids, and other group insecticides

VII. Practicals

- Preparation and characterization of organochlorine insecticides and their intermediates, metabolites and degradation products
- Preparation of representative organochlorine insecticide like dicofol
- Preparation of representative organophosphorus insecticide
- Preparation and characterization of a pesticide intermediate (oxime/oxime ether/ester etc.)
- Phytotoxicity evaluation of insecticides through germination and growth inhibition study
- Bioefficacy of insecticides against stored grain insect pests

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will stand exposed to recent developments in agrochemicals and their use in insect, mite and termite management in crops, food commodities as well as buildings and wooden structures

X. Suggested Reading

- Melnikov NN. 1971. *Chemistry of Pesticides* (Ed: Gunther, F. A., Gunther, J. D. (Eds.), Springer Nature, Springer-Verlag New York, 480 pp
- Eto M. 1979. *Organophosphorus Pesticides: Organic and Biological Chemistry*. CRC Press.
- Kuhr RJ &Dorough HW. (1979). *Carbamate Insecticide Chemistry and Biochemistry*. CRC Press
- Fest C, Schmidt KJ. 1982. *The Chemistry of Organophosphorus Pesticides*, pp 362, DOI10.1007/978-3-642-68441-8, Springer-Verlag Berlin Heidelber
- Leahey JP. 1985. *The Pyrethroid Insecticides*. Taylor & Francis.
- Matolcsy G, Nadasy M and Andriska V. 1988. *Pesticide Chemistry*. Elsevier.
- Matolcsy M, Nádasy V Andriska. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, 1989, pp 805
- Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley.
- Stenersen J. 2004. *Chemical Pesticides Mode of Action and Toxicology*. (ISBN-13: 978-0748409105), CRC Press; 1 edition., 296 pages.
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection,*

Public Health, Environmental Safety. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.

- Singh DK. 2012. *Pesticide Chemistry and Toxicology* (*Book Series: Toxicology: Agriculture and Environment) Volume 1, pp 142*. DOI: 10.2174/9781608051373 1120101 (Benntham eBook)
- Hassall KA. 2013. *The Chemistry Of Pesticides Their Metabolism, Mode Of Action And Uses In Crop Protection* (ISBN: 9789386237118, 9386237113), Scientific Publishers India, pp 372.
- ICAR Institute/SAU *Practical Manual on Agrochemicals for Insect, Mite and Termite Management*

I. Course Title : Agrochemicals for Disease Management

II. Course Code : AC 507

III. Credit Hours : 2+1

IV. Why this course?

Plant diseases are caused by a diverse group of microorganisms which include fungi, bacteria, viruses, plant parasitic nematodes, etc. Besides reducing crop yield, they also reduce quality of the crop produce. Students must learn about diverse range of fungicidal and nematicidal products and their use in plant disease control

V. Aim of the course

To teach students about the chemistry and use of synthetic fungicides and nematicides and their role in plant diseases and nematode management.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to Fungicides and Plant Disease Management	1. Important Plant Pathogenic Fungi, Diseases and Fungicides 2. Classification of Fungicides
2.	Chemical Control of Plant Diseases	1. Inorganic and Dithiocarbamate Fungicides 2. Heterocyclic and Organophosphorus Fungicides 3. Strobilurin (β-Methoxy-Acrylate) Group Fungicides 4. Miscellaneousand New Emerging Fungicides
3.	Chemical Control of Plant Parasitic Nematodes	1. Chemistry, Use and Mode of Action of Chemical Nematicides
4.	Fungicide Resistance	1. Fungicide Resistance and its Management

VI. Theory

Block 1: Introduction to Fungicides and Plant Disease Management

Unit 1: Important Fungicides, Plant Pathogenic Fungi and Diseases

Historical development of fungicides, Some important plant pathogenic fungi and crop diseases, Fungicide movement (translocation) in plant

Unit 2: Classification of Fungicides

Fungicide classification based on chemical nature, Fungicide classification based on mode of action.

Block 2: Chemical Control of Plant Diseases

Unit 1: Inorganic and Dithiocarbamate Fungicides

Chemistry, use and mode of action of inorganic fungicides (S, Cu, Hg, Sn, As), Dithiocarbamate fungicides.

Unit 2: Heterocyclic and Organophosphorus Fungicides

Chemistry, use and mode of action of heterocyclic fungicides (Imidazole, benzimidazole, triazole, oxazole, thiazole, pyridine, pyrimidine, quinoline, quinoxaline, morpholine etc.), Organophosphorus fungicides.

Unit 3: Strobilurin (â-methoxy-acrylate) Group Fungicides

Chemistry, use and mode of action of strobilurin (-methoxyacrylaye) group synthetic fungicides e.g. azoxystrobin, kresoximmethyl, picoxystrobin, fluoxastrobin, pyraclostrobin and trifloxystrobin.

Unit 4: Miscellaneous and New Emerging Fungicidal Molecules

Chemistry, use and mode of action of phenol, quinone, polyhalogen, alkane sulfenyl group, formamide, alkane, alkane carboxylic acid carboxamide and dicarboximide group of fungicides, Chemistry of newly discovered fungicide molecules

Block 3: Chemical Control of Plant Parasuitic Nematodes

Unit 1: Chemical Nematicides

Plant parasitic nematodes, Historical development of nematicides. Preparation, properties and uses of aliphatic halogen compounds, methyl isocyanate liberators, organophosphates and carbamates for nematode control.

Block 4: Fungicide Resistance

Unit 1: Fungicide Resistance and its Management

Definition and development of fungicide resistance in crop pathogens, Fungicide Resistance Action Committee (FRAC) guidelines for resistance management, Fungicide resistance status in India

VII. Practicals

- Preparation of chemical fungicide intermediate(s) like triazoles/ benzimidazoles
- Preparation and characterization of some important fungicides (e.g. Zineb, Bordeaux mixture, Burgundy mixture, dichlorophen, Glyodin, DBCP (nematicide), and an organophosphorus fungicide
- Determination of antifungal activity of the representative test agrochemical (bioassay)
- Characterization of the select fungicides by spectral (IR, UV, NMR or MS) analysis

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the recent developments in agrochemicals and their use in plant disease and nematode management in agricultural crops

X. Suggested Reading

- Matolcsy M, Nádasy V, Andriska. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, 1989, pp 805
- Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley.
- Dehne HW, Deising HB, Gisi U, Kuck KH, Russell PE, Lyr H. (Eds.). 2008. *Modern Fungicides and Antifungal Compounds V.* Proceedings of the 15th International Reinhardsbrunn Symposium on Modern Fungicides and Antifungal Compounds. Friedrichroda, Germany (May 06 – 10, 2007), Deutsche Phytomedizinische Gesellschaft, Braunschweig, Germany, 2008 - ISBN 978-3-941261-02-0
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection, Public Health, Environmental Safety*. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.
- Carisse O. 2010. (Ed) Fungicides, (ISBN 978-953-307-266-1) Publisher: InTechJanezaTrdine 9, 51000 Rijeka, Croatia. pp 538. (A free online edition of this book is available at www.intechopen.com)
- Lukens RJ. *Chemistry of Fungicidal Action* (ISBN: 9783662113134, 3662113139). Springer-Verlag, Berlin, Heidelberg, Germany.
- Singh DK. 2012. *Pesticide Chemistry and Toxicology* (*Book Series: Toxicology: Agriculture and Environment) Volume 1, pp 142.* DOI: 10.2174/97816080513731120101 (Benntham eBook)
- Hassall KA. 2013. *The Chemistry of pesticides, their metabolism, mode of action and uses in Crop Protection* (ISBN: 9789386237118, 9386237113) Scientific Publishers India, pp 372.
- Oliver and Hewitt H. (Eds). 2014. *Fungicides in Crop Protection*, CABI, Oxfordshire, OX10 8DE, UK pp 200 Pages
- ICAR Institute/SAU. *Practical Manual on Agrochemicals for Fungi and Nematode Management*

I. Course Title : Agrochemicals for Weed and Crop Management

II. Course Code : AC 508

III. Credit Hours : 2+1

IV. Why this Course?

Weeds compete with the crop plant for light, space, water and nutrients and hamper the overall growth of the desired crop. Chemical herbicides are employed to kill or control such weeds. This course provides detailed information about the chemistryand mode of action of diverse group of herbicides for weed management and PGRs for crop growth

V. Aim of the Course

To apprise the students about the chemistry, mode of action and use of different classes of herbicides for weed management, and plant growth regulators for crop growth.

The course is organized as follows:

No.	Blocks	Units
1.	Herbicides and Weed Management	1. Introduction to Herbicides and Weed Management
2.	Aliphatic, Aromatic, and other Group Herbicides	1. Aliphatic and Aromatic Acid Group Herbicides

No.	Blocks	Units
		2. Carbamate, Substituted phenyl urea, and s-Triazine 3. group Herbicides 4. Diphenyl Ethers, Dinitroanilines, Amide, and 5. Anilide Group Herbicides
3.	Heterocyclic and Sulfonyl Urea Herbicides	1. Chemistry and Use of Heterocyclic and Sulfonyl Urea Group Herbicides
4.	Plant growth regulators, herbicide safeners, and newly discovered herbicidal molecules	1. Chemistry and Use of Plant Growth Regulators and Herbicide Safeners 2. Newly Discovered Herbicidal Molecules
5.	Herbicide resistance	1. Herbicide resistance and its management

VI. Theory

Block 1: Herbicides and Weed Management

Unit 1: Introduction to Herbicides and Weed Management

Important crop weeds, Introduction to synthetic herbicides, Classification of herbicides based on time of application, mode of action and selectivity, Herbicide resistance and its management

Block 2: Aliphatic and Aromatic Group Herbicides

Unit 1: Aliphatic Acid and Aromatic Acid Group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship of aliphatic and benzoic acid herbicides, phenoxy acid herbicides, phenoxy-phenoxy acid and phenoxy-phenoxy alkanoic acid herbicides

Unit 2: Carbamate, Substituted phenyl urea, and s-Triazine group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship of carbamate, thiocarbamate, biscarbamate, oxime carbamate, sulfonyl carbamate, Substitutred phenyl urea herbicides, s-Triazine group herbicides

Unit 3: Diphenyl Ethers, Dinitroanilines, Amide, and Anilide Group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship ofdiphenyl ethers, dinitroanilines, amide, and anilide group herbicides

Block 3: Heterocyclic and Sulfonyl Urea Herbicides

Unit 1: Chemistry and Use of Heterocyclic and Sulfonyl Urea Group Herbicides

Chemistry, use, mode of action and factors governing structure activity relationship of triazine, pyridine, bipyridylium, pyridazine, pyrimidine, oxadiazole, imidazolinoneand sulfonylurea and sulfonylamides herbicides

Block 4: Plant Growth Regulators, Herbicide Safeners, and Newly Discovered Herbicidal Molecules

Unit 2: Chemistry and Use of Plant Growth Regulators and Herbicide Safeners

Chemistry and use of plant growth regulators (auxins, gibberallin, cytokinins, brassionosteroids, triacontanol, protein hydrolysates), Synthesis, structure activity relationships of auxins and gibberellins, Herbicide safeners and pro-safeners

Unit 3: Newly discovered Herbicidal Molecules

Structure and herbicidal activity of newly discovered herbicidal molecules

Block 5: Herbicide Resistance

Unit 1: Herbicide resistance and its management

History and types of herbicide resistance, Factors and mechanism of herbicide resistance, Management of herbicide resistance

VII. Practicals

- Synthesis and characterization of 2,4-D by m.p, TLC, and NMR,
- Identification and collection of weed samples from Institute research farm.
- Preparation of propionyl chloride and its use in the synthesis of the propanil herbicide
- Synthesis of maleic hydrazide and its characterization by TLC, NMR,
- Estimation of 2,4-D, alachlor, propanil, simazine and/or other available herbicides by HPLC and spectrophotometry.

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will be well versed with safe use of herbicides for weed management and PGR for crop growth

X. Suggested Reading

- Kearnay PC and Kaufman DD. 1975. *Herbicides: Chemistry, Degradation and Mode of Action*. Vols. I, II. Marcel Dekker.
- Matolcsy G, Nadasy M and Andriska V. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, pp 805
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley
- Kramer WK and Ulrich Schirmer. 2007. *Modern Crop Protection Compounds*. Wiley-vch Verlag Gmbh.
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection, Public Health, Environmental Safety*. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.
- Sondhia S and Varshney JG. 2010. Herbicides. Satish Serial Publication House, New Delhi. P 567.
- Rao VS. CRC Press, 2000. *Principles of Weed Science*, 2nd Edition, 566 pp, ISBN 9781578080694 - CAT# N00115
- ICAR Institute/SAU. *Practical Manual on Agrochemicals for Weed and Crop Management*

I. Course Code : Chromatographic and Spectroscopic Techniques

II. Course Title : AC 509

III. Credit Hours : 2+1

IV. Why this course?

The chromatographic (GC, HPLC) and spectroscopic (IR, UV, NMR) methods are necessary tools for the detection, identification, and quantitation of organic molecules. The knowledge of such analytical techniques is necessary for the students pursuing research in R & D of pesticides and allied agrochemicals

V. Aim of the course

To acquaint the students with the chromatographic and spectroscopic techniques and their use in analysis and characterization of organic compounds.

The course is organized as follows:

No.	Blocks	Units
1.	Chromatographic Techniques	1. Introduction to Separation Science Techniques 2. Gas Chromatography (GC) and its Application 3. High Performance Liquid Chromatography (HPLC) and Its Application
2.	Spectroscopic Techniques	1. UV, Visible and IR Spectrophotometry, and its Application 2. NMR (^1H, ^{13}C) Spectroscopy and its Application 3. Mass Spectroscopy (MS) and its Application 4. Tandem Chromatographic and Spectroscopic Techniques

VI. Theory

Block 1: Chromatographic Techniques

Unit 1: Introduction to Separation Science Techniques

Principles of separation science, GC, GPC, and LC chromatography, Super critical fluid chromatograph (SCFC), and Ion exchange chromatography (IEC)

Unit 2: Gas Chromatography and its Application

Theory, principle and instrumentation of GC, GC detectors and columns of different types, Application of GC in analysis of organic compounds, Advantages and limitations of GC

Unit 3: High Performance Liquid Chromatography (HPLC) and its Application

Theory, principle and instrumentation of HPLC, LC detectors and columns of different types, Mobile phase, Application of HPLC in separation and analysis of organic compounds. Advantages and limitations of HPLC

Block 2: Spectroscopic Techniques

Unit 1: UV, Visible and IR Spectrophotometry and its Application

Theory, principle, and instrumentationof absorption (UV, Visible and IR) spectroscopy, Application of UV and IR in structure elucidation of organic compounds

Unit 2: NMR (^{1}H, ^{13}C) Spectroscopy and its Application

Theory, principal and instrumentation of NMR (^{1}H, ^{13}C) spectroscopy, Application of NMR spectroscopy in characterization of organic compounds

Unit 3: Mass Spectroscopy (MS) and its Application

Theory, principal, instrumentation of mass spectroscopy, Mass fragmentation pattern, Application of MS in structure elucidation and confirmation

Unit 4: Tandem GC-MS and LC-MS Techniques

Tandem chromatographic and spectroscopic techniques (GCMS-MS/LCMS-MS), Application of tandem techniques for confirmation of the chemical structure of the analyte constituents.

VII. Practicals

- Separation of organic compound mixture by GC and HPLC
- Application of UV and IR spectrophotometry for detection of organic compounds
- Identification and structure elucidation of organic compounds by NMR (^{1}H, ^{13}C) and MS
- Identification and structure elucidation of organic compounds by GC-MS, LC-MS and MS fragmentation pattern

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire working knowledge of chromatographic and spectroscopic methods for detection, identification, and quantitation of organic molecules.

X. Suggested Reading

- Sharma JM and Follweiler J. 1984. CRC. *Handbook of Chromatography: Pesticides and Related Organic Chemicals*. CRC Press
- Friebolin H and Becconsall JK. 1993. Basic One- and Two-Dimensional NMR Spectroscopy. John Wiley & Sons.
- Dyer JR. 1994. *Application of Absorption Spectroscopy of Organic Compounds*. Prentice Hall of India.
- Silverstein RM, Bassler GC and Morrill TC. 2005. *Spectrometric Identification of Organic Compounds*. 4th Ed. John Wiley & Sons. pages 512.
- Braithwaite A, Smith JF. 1999. *Chromatographic Methods* DOI 10.1007/978-94-011-0599-6, Springer Netherlands, pp 580
- Cazes J and Scott RPW. 2002. *Chromatography Theory* (Chromatographic Science, 88), CRC Press; 1 edition, 496 pages
- Williams DH and Fleming I. 2004. *Spectroscopic Methods in Organic*. Chemistry, Tata McGraw-Hill Education, New Delhi, India, pages 322.
- Nikalje. 2017. *A Handbook of Chromatography* (Editor: Marco Braga), Publisher: Scholar's Press Verlag Omniscriptam, Deutschland, Germany. (ISBN: 978-3-330-65032-9).
- *Practical Manual on Chromatographic and Spectroscopic Techniques* developed by the ICAR Institute/SAU.

I. Course Title : Pesticide Residue Chemistry

II. Course Code : AC 510*

III. Credit Hours : 2+1

IV. Why this course?

Pesticides are inherently toxic and their non-judicious use leaves behind toxic residues. Therefore it needs to be ensured that food commodities we consume are devoid of residues. This course provides exposure to analysis of pesticide residues in food commodities as well as in the soil and aquatic environment. It also provide information about consumer risk assessment and MRL fixation

V. Aim of the course

To teach the students extraction, cleanup, recovery and analysis techniques, develop and validate analytical methodology for risk assessment and MRL fixation.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to Pesticide Residue Chemistry	1. Pesticide Residue – Concept and Significance 2. Laboratory Data and Proficiency Testing
2.	Analysis of Pesticide Residues	1. Extraction, Clean Up and Recovery 2. Method Development and Validation 3. Monitoring of Pesticide Residue in Food Commodities
3.	Consumer Risk Assessment and MRL Fixation	1. Consumer Risk Assessment 2. MRL Fixation of Pesticides in Food Commodities

VI. Theory

Block 1: Introduction to Pesticide Residue Chemistry

Unit 1: Pesticide Residue – Concept and Significance

Pesticide residue definition, source, Significance of Certified Reference Materials (CRMs) in pesticide residue analysis, Planning and layout of experiments, Good agricultural practices (GAP) and experimental design, Post-harvest interval (PHI)

Unit 2: Laboratory Data Documentation and Proficiency Testing

Documentation and audit of laboratory data, Inter laboratory comparison and laboratory proficiency testing, legal implications of pesticide residue data

Block 2: Analysis of Pesticide Residues

Unit 1: Extraction, Clean Up and Recovery

Sampling, sample processing and testing, Different extraction and clean up techniques for optimum recovery

Unit 2: Method Development and Validation

Method development, Validation and performance verification through linearity, sensitivity, matrix effect, limit of quantification (LOQ), limit of detection (LOD), accuracy and precision of recovery, Measurement uncertainty (MU)

Unit 3: Monitoring of Pesticide Residue

Monitoring of pesticide residue in agricultural produce and environment, Multiresidue analysis by quick, easy, cheap, effective, rapid and safe (QuEChERS) method, GC/LC, GC-MS, LC-MS method. ELISA and Radiotracer techniques in residue analysis.

Block 3: Consumer Risk Assessmentand MRL Fixation

Unit 1: Consumer Risk Assessment

Hazard and risk, Ecological and human health risk assessment, Acceptable daily intake (ADI), theoretical maximum daily intake (TMDI),estimated daily intake, Maximum Residue Limit, No Observed Adverse Effect level (NOAEL), Food factor.

Unit 2: MRL fixation of Pesticides in Food Commodities

Safe waiting period, Lowest, highest and median residue data, OECD MRL Calculator, Significance of Codex, EU and FSSAI MRLs.

VII. Practicals

- Collection, storage and preparation of samples for pesticide residue analysis
- Extraction and clean-up of food, soil and water sample prior to analysis of pesticide residues
- Study the percent recovery of pesticide residues from vegetable, soil, and/or water samples fortified with the standard pesticide analyte
- Validation of analytical method by studying linearity, matrix effect, LOD, LOQ, accuracy (recovery) and precision as per SANTE guidelines
- Identification of organochlorine insecticides in soil and water by TLC/GC/HPLC
- Identification of Carbamate insecticides in water by TLC/GC/HPLC,
- Estimation of carbamate insecticide residues in vegetable by visible spectroscopic method and HPLC
- Estimation of OP insecticide residues in soil by spectroscopic method and HPLC.

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge aboutthe pesticide residue analysis, consumer risk assessment and MRL fixation

X. Suggested Reading

- Handa SK, Agnihotri NP and Kulshrestha G. 2000. *Pesticide Residue Analysis, Significance, Management and Analysis*.
- Gupta A. 2006. *Pesticide Residue in Food Commodities*. Agrobios (India).
- FAO. 2009b. *Submission and evaluation of pesticide residues data for the estimation of maximum residues levels in food and feed* (FAO Plant production and protection paper 197) <http://www.fao.org/ag/AGP/AGPP/Pesticide/p.htm>.
- FAO/WHO. 2013. *Codex Pesticides Residues in Food Online Database*. Pesticide Residues in Food and Feed, doi: http://www.codexalimentarius.net/pestres/data
- Sharma KK. 2013. *Pesticide Residue Analysis Manual* (Second edition), Directorate of

Knowledge Management in Agriculture, ICAR, KAB-I, Pusa, New Delhi-110012, India. pp 248

- Sondhia S. 2014. *Herbicides residues in soil, water, plants and non-targeted organisms and human health implications: an Indian perspective*. Indian Journal of Weed Science 46(1): 66–85.
- FSSAI. 2015. *Food Safety Standard Authority of India*, Fixation of MRL.
- Mohidus SK and Mohammad SR. (Eds.). 2017. *Pesticide Residue in Foods: Sources, Management and Control*. DOI 10.1007/978-3-319-52683-6, Springer Interntnl. Publishing, pp 200.
- SANTE. 2017. *Guidance document on analytical quality control and validation procedures for pesticide residues analysis in food and feed*. European Commission Health and Consumer Protection Directorate–General. SANTE/11813/2017 Supersedes SANCO/11945/2015.
- ICAR Institute/SAU. *Practical Manual on Pesticide Residue Chemistry*

Course Title with Credit Load
Ph.D. in Agricultural Chemicals

Course Code	Course Title	Credit Hours
AC 601*	Agrochemical Formulation Technology	2+2
AC 602*	Chemistry of Biopesticides	2+1
AC 603	Advanced Organic Chemistry	2+1
AC 604	Pesticide Metabolism, Persistence, and Decontamination	2+1
AC 605	Term Paper (Special Topics In Agrochemicals)	1+0
AC 691	Doctoral Seminar-I	1+0
AC 692	Doctoral Seminar-II	1+0
AC 699	Doctoral Research	75

*Core courses

Course Contents
Ph.D. in Agricultural chemicals

I. Course Title : Agrochemical Formulation Technology

II. Course Code : AC 601*

III. Credit Hours : 2+2

IV. Why this course?

Several advancements have been reported in pesticide formulation technology. The course intends to cover recent developments on the subject and will be useful to students interested in pursuing research in R & D of pesticide formulation technology

V. Aim of the course

To apprise the students about the recent developments in formulation technology and delivery systems.

The course is organized as follows:

No.	Blocks	Units
1.	Conventional Pesticide Formulations	1. Overview of Conventional Pesticide Formulations 2. Selection of Adjuvants and Synergists in Formulation Chemistry 3. Physico-Chemical Properties of Pesticide Formulations
2.	New Generation Pesticide Formulations	1. Water and Oil Based Novel Formulation 2. Dry, Controlled Release, and Other Novel Formulations 3. Pesticide Application and Delivery 4. Systems
3.	Nanotechnology and its Application in Pesticide Formulation	1. Production and Characterization of Nano-Materials 2. Application of Nanotechnology in Pesticide Formulation and Delivery

VI. Theory

Block 1: Conventional Pesticide Formulations

Unit 1: Overview of Conventional Pesticide Formulations

Solid and liquid formulation, Conventional pesticide formulations such as Dust (D), Granule, pallet (P), Wettable Powder (WP), Emulsifiable Concentrate (EC), and Solution (S). Biopesticide formulations-specifications and types, Limitations of conventional formulations

Unit 2: Selection of Adjuvants and Synergists in Formulation Chemistry

Role of adjuvants (carriers, diluents, surfactants, emulsifiers, dispersing agent, wetting agents, stickers and spreaders, penetrants,safeners, encapsulants etc.), synergists,antioxidants, stabilizers etc. in formulation chemistry.

Unit 3: Physico-chemical Properties of Pesticide Formulations

Physico-chemical properties (solubility, octanol-water partition coefficient, vapor pressure, soil adsorption coefficient, emulsion stability, half-life, shelf-life etc.) and their testing, Formulant-toxicant interactions.

Block 2: New Generation Pesticide Formulations

Unit 1: Water and Oil Based Novel Formulation

Water soluble concentrates (WSC), Suspension concentrates (SC), Oil-in-water emulsion (EW), suspo-emulsion (SE), Micro-emulsion (ME), Water soluble bags and packets(WSB/WSP), Oil dispersion (OD), Aqueous flowable (AF).

Unit 2: Dry, Controlled Release, and Other Novel Formulations

Water soluble powder, liquid and dispersible granules, Dispersion concentrates, Effervescent tablets, Control/time release formulations. Aerosols, baits, fumigants, and formulations of pesticide mixtures, Seed treatment formulations, Seed dressing.

Unit 3: Pesticide Application and Delivery Systems

Packaging and labelling of pesticide formulations, Machinery and equipment for pesticide formulation, Pesticide application and delivery systems - principles, distribution and coverage.

Block 3: Nanotechnology and its Application in Pesticide Formulation

Unit 1: Production and Characterization of Nanomaterials

Development of nanomaterials – bottom up and top-down approach, nano-sizing of inorganic materials, Techniques for characterization of nanomaterials [Zeta sizer, Dynamic light scattering (DLS), X-ray diffraction (XRD), Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Atomic force microscopy (AFM), and Scanning tunneling microscopy (STM)].

Unit 2: Application of Nanotechnology in Pesticide Formulation and Delivery

Production and use of nano-enabled pesticide formulation (nanoemulsions, nanodispersions, nanoencapsulation, and other polymer based formulations), Nanocarriers for targeted and controlled release, Benefits and environmental risks of nanopesticides.

VII. Practicals

- Study of liquid carriers for the determination of (i) flash point, (ii) specific gravity, (iii) viscosity, and (iv) micelle formation with the surfactants
- Study of solid carriers: Determination of (i) Surface acidity by volumetric method, (ii), surface area, (iii) Sorptivity, and (iv)particle size, of the solid carriers
- Preparation of solid formulations: wettable powder (WP)/granules (G)/WDG/WSG
- Physico-chemical analysis of solid formulations based on BIS/CIPAC/FAO guidelines.
- Physico-chemical analysis of liquid/gel formulations based on BIS/CIPAC/FAO guidelines
- Preparation of toxicant based insect repellent formulations.
- Preparation of liquid and gel formulations: EC/SC/SL/OD/EW/gel, etc.
- Preparation and characterization of a nanopesticide formulation

- Preparation of controlled release (CR) formulation and the release of active ingredient in soil and water

VI. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

VII. Learning outcome

After successful completion of the course, student will acquire knowledge about new generation pesticide formulation and their use in pest control

VIII. Suggested Reading

- Chester L. Foy, David W. 1996. Pritchard Pesticide Formulation and Adjuvant Technology. ISBN-13: 978-0849376788. CRC Press, 384 pages
- Knowles DA. 1998. *Chemistry and technology of Agrochemical Formulations* DOI https://doi.org/10.1007/978-94-011-4956-3 Kluwer Academic Publishers, Springer Nature Switzerland AG.
- Alan K. Viets, Jane C. Mueninghoff (Editors). 2001. *Pesticide Formulations and Application Systems*, 20 ASTM International, 2001, 196 pages.
- Jane C. Mueninghoff, Alan K. Viets (Editors) Pesticide Formulations and Application Systems: A New Century for Agricultural Formulations. 21, (1414), ASTM publication. *Journal of ASTM International: Selected technical papers*, ISSN 1040-1695, 260 pages.
- Parmar BS and Tomar SS. 2004. *Pesticide Formulation Theory and Practice*, CBS Publishers & Distributors-New Delhi, ISBN: 9788123911243, 8123911246
- Valkenburg WV. 2008. *Pesticide Formulation: Recent Developments and Their Applications in Developing Countries* (ISBN-13: 978-8122410693) New Age International (P) Limited, Publishers; First edition (2008) pp 488.
- Goss GR (Editor). 2014. *Pesticide Formulation and Delivery Systems*: 35th Volume, Pesticide Formulations, Adjuvants, and Spray Characterization. ISBN-13: 978-0803176195 (Publisher: ASTM International 2016), 93 pages .
- Teicher HB. 2017. *Pesticides and Biopesticides: Formulation and Mode of Action* (Publisher: BioComm Press) pp 166.
- Practical Manual on Pesticide Formulation Technology developed by the ICAR Institute/ SAU.

I. Course Title : Chemistry of Biopesticides

II. Course Code : AC 602*

III. Credit Hours : 2+1

IV. Why this course?

Biopesticides derived from natural sources (plant, animal, nematodes, bacteria, fungi, virus, natural minerals) are considered as safer alternative to chemical pesticides. In view of their safety, such ecologically sound products are increasingly sought after for use in agriculture, veterinary and public health.

V. Aim of the course

To apprise the students about the usefulness of phytochemical biopesticides, microbial pesticides insect behaviour modifying chemicals, and role of biotechnology in pest management.

The course is organized as follows:

No.	Blocks	Units
1.	Phytochemical Biopesticides	1. Conventional Botanical Pesticides 2. New Generation Botanical Pesticides
2.	Insect Behaviour Modifying Chemicals	1. Insect Hormones and Related Products 2. Pheromones and Allelochemicals 3. Insect Feeding Deterrents and Repellents
3.	Microbial Pesticides and Bioagents	1. Microbial Insecticides 2. Microbial Fungicides and Herbicides 3. Entomopathogenic Nematodes, Fungi, and Plant Inhabiting Fungal Endophytes 4. Application of Biotechnology in Pest Management

VI. Theory

Block 1: Phytochemical Biopesticides

Unit 1: Conventional botanical pesticides

Isolation, characterization, use and mode of action of natural pyrethrins, rotenones,nicotine and neem based azadirachtiniods

Unit 2: New generation botanical pesticides

Isolation, characterization, use and mode of action of toosendanin, ryanodine, rocaglamides, annonins, isobutylamides, quassinoids, and sugar esters from plant sources, Plant essential oils and their constituents as botanical pesticides, Photo-activated pesticides like á-terthieyl, acetylenes and acetylenic thiophenes

Block 2: Insect Behaviour Modifying Chemicals

Unit 1: Insect hormones and related products

Insect hormones (Juvenile hormones, Moulting hormones, Brain hormones), their chemistry, mode of action and use in insect pest control)

Unit 2: Pheromones and allelochemicals

Pheromones (sex, alarm, trail, territorial, aggregation, etc.), Semiochemicals, Allelochemicals – allomones, kairomones, synomones, apneumones, Phytoalexins

Unit 3: Insect feeding deterrents and repellents

Sources, chemistry and mode of action of feeding deterrent and insect repellents

Block 3: Microbial Pesticides And Bioagents

Unit 1: Microbial Insecticides

Pesticides of microbial origin, Bacillus (*Bt, Bs*) and NPV based Insecticides. Chemistry and mode of action of macrolides such as avermectins, milbimycins and spinosyns

Unit 2: Microbial Fungicides and Herbicides

Natural fungicides like strobilurins and other methoxyacrylates, Bioherbicides like biolaphos and phosphonothricin

Unit 3: Entomopathogenic Nematodes, Fungi, and Plant Inhabiting Fungal Endophytes

Entomopathogenic nematodes and entomopathogenic fungi in insect control, Pesticidal secondary metabolites (biotoxins) from EPN (*Photorhabdus* and *Xenorhabdus)* and EPF (Metarrahiza etc.), Plant inhabiting fungal endophytes and their role in plant protection

Unit 4: Application of Biotechnology in Pest Management

Plant incorporated protectants, Recombinant DNA technology, **Genetically-modified** (GM) herbicide resistant crops, **Genetically-modified**insect resistant crops, Potential benefits and risks of GM crops

VII. Practicals

- Isolation of curcuminoids from turmeric rhizome and their characterization,
- Extraction of tobacco leaves, isolation of nicotine and its identification,
- Extraction of neem seed kernels to isolate neem oil
- Saponification of neem oil
- Isolation of azadirachtin concentrate from neem seed kernel powder
- Quantification of azadirachtin content in isolated azadirachtin powder
- Characterization of biopesticides by chromatographic and spectral analysis

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will get acquainted with production of biopesticides from natural sources and their use in crop protection as safer alternative to chemical pesticides.

X. Suggested Reading

- Jacobson M. 1970. *Naturally Occurring Insecticides*. Wiley Khan SU. 1980. Pesticides in the Soil Environment. Elsevier.
- Parmar BS and Devakumar C. 1990. *Botanical and Biopesticides*. Westvill Publ. House
- Copping LG. 1996. *Crop Protection Agents from Nature: Natural Products and Analogues*. Royal Soc. Chem., London.
- Dev S and Koul O. 1997. *Insecticides of Natural Origin*. Harwood Acad. Publ. Godfrey CRA. 1995. Agrochemicals from Natural Products. Marcel Dekker.
- Schmutterer H. 2002. *The Neem Tree: Source of unique natural products for integrated pest management, medicine, industry and other purposes*. (2nd edition) Neem Foundation, Mumbai-400 049, India
- Parmar BS, Walia S, Anupama and Kumar J. 2008. *Neem Pesticides in India, An update of the recent developments*. SPS Publication No. 15, Society of Pesticide Science, India 50pp
- Parmar BS and Walia S. 2001. *Prospects and problems of phytochemical pesticides*. In: O. Koul and G.S. Dhaliwal (eds) Phytochemical Biopesticides, Harwood Academic Publishers Gmbh. Netherlands pp 133-210.
- Koul. 2004. *Insect antifeedants*. CRC Press LLC Boca Raton, Florida 33431, USA, pp 1005
- Franklin R. Hall and Julius J. Menn (Ed) *Biopesticides: Use and Delivery*. DOI 10.1385/0896035158, 2010 edition, 626 pages. Humana Press, Springer Nature. Switzerland. AG
- Singh D. 2014. *Advances in Plant Biopesticides*, Springer Nature India Private Limited, DOI 10.1007/978-81-322-2006-0. Pages 421.

- Leo ML. Nollet and Rathore HS. 2017. *Green Pesticides Handbook: Essential Oils for Pest Control* (ISBN-13: 978-1498759380), CRC Press pp 570.
- ICAR Institute/SAU. *Practical Manual on Chemistry of Biopesticides.*

I. Course Title : Advanced Organic Chemistry

II. Course code : AC 603

III. Credit Hours : 2+1

IV. Why this course?

This course provides a deeper understanding of organic chemistry and covers advanced topics of stereochemistry, photochemistry, pericyclic reactions, name reactions, chemical reagents etc. The knowledge of advanced organic chemistry is essential to students interested in synthesis and technology development of organic compounds including pesticides

V. Aim of the course

The course aims to equip the students with the advanced knowledge about stereochemistry, chemical reactions, chemical reagents in organic synthesis, and photochemistry.

The course is organized as follows:

No.	Blocks	Units
1.	Stereochemistry	1. Understanding Spatial Arrangement of Organic Molecules 2. Application Of Stereochemistry
2.	Important Chemical Reactions and their Mechanisms	1. Electrophilic and Nucleophilic Substitution Reactions 2. Elimination and Addition Reactions 3. Pericyclic Reactions 4. Organic Name Reactions
3.	Reagents in Organic Synthesis	1. Different Reagents and their Application in Organic Synthesis 2. Protection and Deprotection of Functional Groups
4.	Photochemistry	1. Basic Principles and Application of of Photochemistry

VI. Theory

Block 1: Stereochemistry

Unit 1: Understanding Spatial Arrangement of Organic Molecules

Enantimerism and diastereoisomerism, mesomers, Racemic mixture (racemate), Different methods of resolution of enantiomers (optical resolution), Walden inversion, Asymmetric synthesis of stereoisomers

Unit 2: Application of Stereochemistry

Nomenclature of stereo-chemicals with particular reference to agrochemical molecules, Stereospecific and stereoselective reactions, Chiral synthesis

Block 2: Important Chemical Reactions and their Mechanisms

Unit 1: Electrophilic and Nucleophilic Substitution Reactions

Electrophilic aromatic and Electrophilic aliphatic substitution reactions, Nucleophilic substitution reactions, (SN1, SN2 and SNi), Reactions involving carbonium ion, carbanion, carbene and free radicals.

Unit 2: Elimination and Addition Reactions

Elimination reactions (*syn* vs. *anti*-elimination, orientation in elimination reaction, molecular rearrangement, decarboxylation reactions, etc.). Addition reactions. Electrophilic addition of bromine. hydrogenation, hydroboration

Unit 3: Pericyclic Reactions

Cyclic transition states, Types of pericyclic reactions - cycloadditions, sigmatropic rearrangements, and electrocyclic reactions.

Unit 4: Organic Name Reactions

(i) Diels Alder reaction, (ii) Grignard reaction, (iii) Aldol, condensation, (iv) Perkin reaction, (v) Benzoin condensation, (vi) Friedel Craft alkylation and acylation reaction, (vii) Fries rearrangement (viii) Reformatsky reaction, (ix) Wittig Reaction and Sandmeyer reaction (x) Oppenaeur oxidation, (xi) Ziegler Natta reaction

Block 3: Reagents in Organic Synthesis

Unit 1: Different Reagents and their Application in Organic Synthesis

Reagents in organic synthesis: complex metal hydrides, Gilman's reagent, lithium dimethyl curparate, lithium di-isopropyl amide (LDA), dicyclohexylcarbodimide, 1,3-di-thiane, trimethyl selyl iodide, triselenium dioxide, tri-butyl tin hydride, osmium tetroxide, dichlorodicyano quinone etc. Organometallic reagents in organic synthesis, phase transfer catalysis, crown ethers and Merrifield resins

Unit 2: Protection and Deprotection of Functional Groups

Different methods of protection of functional groups in organic synthesis with examples, Deprotection to release the functionality

Block 4: Photochemistry

Unit 1: Basic Principles and Application of Photochemistry

Definition and laws of photochemistry, Light-induced excitation of organic molecules, Singlet and triplet state of oxygen, Application of photochemistry in biological systems, agriculture and industry. Role of light in degradation of pesticides and related xenobiotics

VII. Practicals

- One experiment each of methylation, acetylation, elimination, oxidation, reduction, and hydrolysis
- Preparation of acid chlorides, amides, esters,
- Friedal craft reaction (Alkylation/Acylation),
- Aldol/Claisen/Schmidt reaction,
- Pechmann condensation/Perkin reaction,
- Characterisation of prepared organic compounds by NMR and IR spectroscopy

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will get familiar with advanced organic chemistry and its application for planning, understanding and conducting organic reactions

X. Suggested Reading

- Finar IL. *Organic Chemistry*, Longman Publishing Group
- Corey FA and Sundberg RJ. 1983. *Advanced Organic Chemistry. Subseries:* Part A. *Structure & Mechanism*. Part B. *Reaction and Synthesis.* 2nd Ed. Plenum Press,
- Morrison RT, and Boyd RN. 1992. *Organic Chemistry*, 6th edition, ISBN 0136400612 (ISBN13: 9780136436690) Prentice Hall, 1278 pages.
- Eliel EL and Wilen SH. 1994. *Stereochemistry of Organic Compounds*. John Wiley & Sons. Finar IL. 1959. *Text book of Organic Chemistry*. Vols. I, II. 25th Ed. Pearson Edu.
- Kalsi PS. 1996. *Stereochemistry and Mechanism through Solved Problems*. 2nd Ed. New Age International Publ.
- Peter Sykes. 1996. *Organic Chemistry. Guidebook to Mechanism in Organic Chemistry*. 6th Ed. Prentice Hall.
- Vogel AI. 1996. *Vogel's Textbook of Practical Organic Chemistry*. 5th Ed. Printice Hall.
- Ahluwalia VK and Aggarwal R. *Comprehensive Practical Organic Chemistry - Preparation and Quantitative Analysis*. Universities Press.
- Bahl A and Bahl BS. 2005. *A Textbook of Organic Chemistry*, S Chand and Company, New Delhi, India, 1074 pages.
- Smith MB and March J. 2007. *March's Advanced Organic Chemistry Reactions, Mechanisms, And Structure*, John Wiley & Sons, Inc., Hoboken, New Jersey, 2190 pages
- Clayden J, Geeves N, Warren S. 2012. *Organic Chemistry* 2nd Edition (ISBN: 978-0199270293), Oxford University Press, Pages 1234.
- ICAR Institute/SAU *Practical Manual on Advanced Organic Chemistry*

I. Course Title : Pesticide Metabolism, Persistence and Decontamination

II. Course Code : AC 604

III. Credit Hours : 2+1

IV. Why this ourse?

The study of pesticide metabolism and dynamics is necessary to understand behaviour of pesticides in the biological systems and the environment. The course is designed to provide deep understanding of the biotic and abiotic transformations affecting fate of the pesticides in the environment

V. Aim of the ourse

To acquaint the students about the persistence, dissipation, and fate of pesticides in the crops and the environment. and about bio-remedial measures to decontaminate pesticide residues.

The course is organized as follows:

No.	Blocks	Units
1	Pesticide Movement in the Environment	1. Translocation of Pesticides in the Plant, Soil and Aquatic Environment 2. Different Phases of Pesticide Metabolism
2	Abiotic and Biotic Transformations of Pesticides	1. Abiotic Transformation of Pesticides 2. Microbial Degradation of Pesticides 3. Metabolism of Pesticides in the Living Systems
3	Pesticide Persistence and Dissipation Kinetics	1. Persistence of Pesticides in the Environment (Soil, Water and Crops) 2. Pesticide Dissipation and Fate in the Environment
4.	Decontamination and Bioremediation Measures	1. Decontamination of Pesticide Residues 2. Bioremediation of Pesticides and Pesticide Contaminated Sites

VI. Theory

Block 1: Pesticide Movement in the Environment

Unit 1: Translocation of Pesticides in the Plant, Soil and Aquatic Environment

Introduction to pesticide metabolism, penetration, uptake, translocation, excretion, and mineralization etc. (Highlight the role of physico-chemical parameters). Uptake, bio-accumulation, bio-concentration, and biomagnifications of pesticides in the plant and the environment.

Unit 2: Different Phases of Pesticide Metabolism

Fate of pesticides in the plant, animal and other living systems, Phase I metabolism (oxidation, reduction, hydrolysis, enzymatic degradation, etc.), Phase II metabolism (conjugation with sugar, amino acid, glutathione, etc.), Phase III metabolism (further conjugation of phase II metabolites), Non-extractable (Bound) residues.

Block 2: Abioticand Biotic Transformations of Pesticides

Unit 1: Abiotic Transformations of Pesticides

Physical and chemical factors affecting fate of pesticides in the environment, Photochemical transformation of pesticides, Role of photosensitizers, quenchers, and light filters in pesticide degradation.

Unit 2: Metabolism of Pesticides in the Living Systems

Biotic transformations and metabolic pathways of different group pesticides in thecrops, insects, animal models.

Unit 3: Microbial Degradation of Pesticides

Types of pesticides-degrading microorganisms in the environment, Factors affecting microbial degradation, Microbial degradation of different group pesticides.

Block 3. Pesticide Persistence and Dissipation in the Environment

Unit 1: Persistence of Pesticides in the Environment

Low, moderate and high persistent pesticides, Persistent organic pollutants, Physical, chemical, biochemical and environmental factors affecting pesticide persistence in the environment.

Unit 2: Pesticide Dissipation and Fate in The Environment

Various dissipation processes, Role of drift, volatilization, adsorption, desorption, runoff etc.in pesticide dissipation, Leaching and risk of groundwater pollution, Dissipation time (Half-life-DT_{50}, DT_{90}), Rate kinetics (1st order, 2^{nd} order), Behaviour and fate of pesticides in soil and crops.

Block 4: Decontamination and Bioremediation Measures

Unit 1: Decontamination of Pesticide Residues

Decontamination of pesticide residues in water and food (vegetables and fruits) commodities, Effect of different processing/culinary methods on reduction pesticide residues, safer methods of pesticide decontamination.

Unit 2: Bioremediation of Pesticides and Pesticide Contaminated Sites

Bioremediation-advantages and applications, Biodegradation and bioremediation of pesticides and related xenobiotic compounds, Microbe-mediated bioremediation, Use of enzymes in bioremediation, bioremediation of pesticide polluted sites.

VII. Practicals

- Synthesis of a pesticide metabolite
- Photodegradation of pesticides on glass and leaf surface,
- Microbial degradation of pesticides in soil.
- Leaching of pesticides in soil columns,
- Recovery of residues from pesticide-spiked farm soil

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about pesticide metabolism and dynamics in the biological systems and the environment and get acquainted with bio-remedial measures for to decontaminating food commodities and pesticide contaminated sites

X. Suggested Reading

- Schnoor JL. (Ed). 1992. *Fate of pesticides and chemicals in the environment*. Wiley New York. 436 pages:
- Alexander M. 1999. *Biodegradation and bioremediation*. 2nd Ed. Academic Press.
- Racke KD, Skidmore MW, Hamilton DJ, Unsworth JB, Miyamoto J and Cohen SZ. 1997. *Pesticide Fate in Tropical Soils*. Pure and Appl. Chem. 69 (6): 1349-1371.
- Hall JC, Hoagland RE and Zablotowicz RM. 2001. *Pesticide Biotransformation in Plants and Microorganisms: Similarities and Divergences*. ACS Symposium Series 777. Washington, DC.
- Shahamat U Khan. 1980. *Pesticides in the Soil Environment* (Editor: R. J. Wakeman) Elsevier. 248 pages.
- Perry AS, Yamamoto I, Ishaaya I, Perry RY. 1998. Insecticides in Agriculture and Environment- Retrospects and Prospects, DOI: 10.1007/978-3-662-03656-3 pp 261. Springer-

Verlag Berlin Heidelber.
- Wheeler WB. (Ed) 2002. *Pesticides in Agriculture and the Environment* (1st Edition), CRC Press.
- Matsumura F (Ed) 2013. *Biodegradation of Pesticides* (ISBN-13: 978-1468440904) Publisher: Springer, pp 312 pages.
- ICAR Institutes/SAU. *Practical Manual on Pesticide Residues and Dynamics in the Environment*

I. Course Title : Term Paper (Special Topics in Agro Chemicals)

II. Course code : AC 605

III. Credit Hours : 1+0

IV. Aim of the course

To develop proficiency of the student in his/her area of specialization. The teacher will give a topic relevant to the area of specialization of the student as a term paper to develop proficiency in his field of research. The term paper can be based on one of the selected current topics in agrochemicals

V. Suggested Reading

Literature on the relevant subject of the term paper in his area of research

Journals

- *Archives of Environmental Contamination and Toxicology*
- *Biopesticide International*
- *Bulletin of Environmental Contamination and Toxicology*
- *Chemosphere*
- *Crop Protection*
- *Current Science*
- *Environment Monitoring and Assessment*
- *Environmental Toxicology and Chemistry*
- *Food Additives and Contaminants*
- *Food Chemistry*
- *Indian Journal of Agricultural Chemistry*
- *Industrial Crops and Products*
- *Integrated Pest Management Reviews*
- *International Journal of Pest Management*
- *International Journal of Pesticide Reform*
- *Journal of Agriculture and Food Chemistry*
- *Journal of AOAC*
- *Journal Environ. Science and Health Part A & B*
- *Journal of Essential Oil Bearing Plants*
- *Outlooks on Pest Management*
- *Pest Management Science*
- *Pesticide Biochemistry and Physiology*
- *Pesticide Research Journal*
- *Pesticide Science Japan*
- *Weed Research*
- *Weed Science*
- *Weed Technology*

e-Resources

- Government of India, Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Plant Protection, Quarantine & Storage. http://ppqs.gov.in/about-us/about-department

- Central Insecticide Board and Registration Committee (CIB&RC) www.cibrc.nic.in; http://ppqs.gov.in/contactus/central-insecticide-board-and-registration-committee-cibrc
- The Food Safety and Standards Authority of India (FSSAI) https://www.fssai.gov.in/home
- *Insecticides in Agriculture and Environment- Retrospects and Prospects*, Authors: Perry, A.S., Yamamoto, I., Ishaaya, I., Perry, R.Y. (1998) DOI: 10.1007/978-3-662-03656-3 pp 261. Springer-Verlag Berlin Heidelber
- *CRC Handbook of pest management in agriculture, Volume 1. Author:* Pimentel, D., CRC Series in Agriculture; Editor: Hanson, A.A.]. 1981. 597 pp.
- Food and Agricultural Organization Statistics (FAOSTAT) *Pesticides Use*. http://www.fao.org/faostat/en/#data/RP
- Food and Agricultural Organization (FAO/WHO) *Codex Pesticides Residues in Food Online Database. Pesticide Residues in Food and Feed*, doi: http://www.codexalimentarius.net/pestres/data
- European Food Safety Authority: http://www.efsa.europa.eu/en/pesticides/mrls.htm
- Pest Management Regulatory Agency Canada. https://www.canada.ca/en/health-canada/corporate/about-health-canada/branches-agencies/pest-management-regulatory-agency.html
- OECD (Organization for Economic Co-operation and Development), (2011). OECD MRL calculator: spreadsheet for single data set and spreadsheet for multiple data set, 2 March 2011. In: Pesticide Publications/Publications on Pesticide Residues. http://www.oecd.org.
- Bureau of Indian Standards (BIS), New Delhi, India. http://www.bis.org.in/cert/bis_proc_obt_lic.htm
- EU. http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=pesticide.residue.CurentMRL&language=EN&pestResidueID=69. (accessed 21 October 2016).
- US Environment Protection Agency (USEPA) https://www.epa.gov, https://www.epa.gov/pesticide-registration/about-pesticide-registration

Suggested broad topics for master's/ doctoral research

- New generation pesticides (insecticides, fungicides, herbicides, nematicides), plant growth stimulants, and other allied agrochemicals from synthetic and botanical sources
- Biopesticides from natural sources (plants, fungi, bacteria, algae, nematodes, etc),
- Novel insect antifeedants and other insect behaviour modifying chemicals (pheromones and other semio-chemicals)
- Novel pesticide formulations, time-release formulations, and delivery systems for enhanced activity and stability of single and combination pesticides
- Analysis of pesticide residues (multi-class pesticides, metabolites, degradation products, impurities) in soil, water, food commodities as well as in technical materials and formulations
- Investigations on safety evaluation, fixation of MRLs and safe waiting periods, and risk assessment
- Biotechnological and nanotechnological intervention for developing ecologically sound agrochemicals
- Pesticide-environment (plant, air, water, microbes) interaction, Pesticide persistence, degradation (biotic, abiotic)
- Impact of pesticides on the non-target organisms.
- Pesticide detoxification, decontamination and disposal, Bioremediation of pesticide contaminated sites for safe environment
- Increasing agricultural input (pesticides, water, fertilizers, micronutrient etc.) use-efficiency through technological interventions.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Biochemistry

Preamble
(Biochemistry)

The global advancement of agriculture in the fields of crop production and improvement, crop protection, development of newer and high yielding varieties of different crops are all going hand-in-hand with the advancement and application of biochemistry. Education and research in agriculture, specifically in the fields of photosynthetic efficiency, nitrogen fixation, applications of recombinant DNA technology, genomics and proteomics in varietal development and plant protection, animal and human nutrition and health and the environmental impact of agricultural chemicals are some examples of the wide array of topics in which biochemistry plays significant contributions.

Restructuring the courses of biochemistry associated with agricultural education in our country has become demand of the day to keep pace with the rapid development of the subject as well as to fulfil the objective of doubling farmer's income through use of these cuttingedge developments under the global context. Keeping this in view the ICAR has initiated modification of the existing courses both of M.Sc. and Ph.D. curricula in biochemistry. These alterations will not only help the students to understand the subject better but will also create ample scope to gather advanced knowledge in different areas of the subject which will enable them to proceed a step further towards excelling in advanced studies and research and also serving the industrial field causing benefit to the mankind.

M.Sc. courses

A total of eleven courses belonging to five different categories have been proposed for M.Sc. programme:

1. Basic and fundamental course: BIOCHEM 501 (Basic Biochemistry) deals with the basic andfundamental aspects of biochemistry. It is one of the core courses of M.Sc. study programme which has the objective to enrich the students of biochemistry as well as other disciplines with the knowledge of the basics of the subject. The students will gather basic idea and will have a strong footing prior to entering into the vast realm of the subject. The topic of photosynthesis in this course is replaced by plant secondary metabolites, PR proteins and immunoglobulins. Several relevant and new practicals have also been introduced.

2. Courses covering the major areas of the subject including one of analytical aspects: This category includes four courses, BIOCHEM 502 (Intermediary Metabolism), BIOCHEM 503 (Enzymology), BIOCHEM 504 (Molecular Biology) and BIOCHEM 505 (Techniques in Biochemistry). Students will be able to have a comprehensive idea of the metabolic processes occurring in the living cells, the catalytic activity of the enzymes in the biological systems and the molecular basis of transmission of hereditary information through generations. These courses will appraise the students about the basic biochemical activities occurring in the living systems and will also help them to choose the avenues of their future research programmes with the knowledge of essential tools of analytical techniques being extremely helpful for the students of other disciplines besides thosebelonging to biochemistry itself. The qualitative and quantitative estimation of the plant metabolites is also an important aspect of crop improvement programmes.

In BIOCHEM 502, topics such as, biochemical reaction types, bioavailability of nutrients, defined metabolic processes, and nucleotide metabolism are newly introduced. Course outlines in BIOCHEM 503 are redefined in broader aspects with introduction of enzyme kinetic models and large scale production technology of enzymes in theory and effect of inhibitors on enzyme activity and electrophoretic analysis of isozymes in practical. New topics for theory have also been added to BIOCHEM 504, such as genome editing, DNA sequencing, *in vitro* mutagenesis and techniques in molecular biology. The course BIOCHEM 505 is redesigned with introduction of several modern and widely used techniques, viz. mass spectroscopy - MS/MS, LC-MS, GC-MS, MALDI-TOF, atomic absorption spectrophotometry, microscopic techniques, imaging techniques – MRI and CT scan and immunochemical techniques. Emphasis is also given to practicals with introduction of several important techniques – separation and analysis of fatty acids/lipids by GC, $(NH_4)_2 SO_4$ precipitation and dialysis, PCR, ELISA and Western blotting/Dot blotting.So the course BIOCHEM 505 will enable the students to acquaint with the methods to estimate the phytochemicals and cellular constituents along with their theoretical backgrounds.

3. Courses related to plant metabolism: Two courses within this category are BIOCHEM 507 (Plant Biochemistry) and BIOCHEM 510 (Nitrogen and Sulphur Metabolism). Understanding the basic plant metabolic processes is of prime importance for improvement of crop plants. So these courses will give the basic idea in this field and will help the students to explore further for development of the crops.

Credit load in BIOCHEM507 is changed from 3 (3+0) to 3 (2+1) with one credit for practicals and with introduction of new topic - effect of biotic and abiotic factors on plant metabolism. For BIOCHEM 510 also, the course title is changed from Carbon and Nitrogen metabolism to Nitrogen and Sulfur metabolism as the topics under carbon metabolism have been well addressed in BIOCHEM 501 and BIOCHEM 507. An elaborative course outline on nitrogen as well as sulfurmetabolism covering all the aspects is prescribed. New practicalslikeestimation of cysteine, methionine, pyruvate and glutathione and assay of APS activity are introduced.

4. Courses dealing with diverse specialized areas: Three courses, viz. BIOCHEM 506 (Immunochemistry), BIOCHEM 509 (Nutritional Biochemistry) and BIOCHEM 511 (Biochemistry on Xenobiotics) under this categoryaddress the biochemical aspects of immunity, nutrition and environmental applications of biochemistryrespectively. These courses will widen the area of understanding as well as application of the subject on environmental components and human health as a whole.

In BIOCHEM 506 course outline, aspects on plant immunity, proteasome mediated process, plantibodies, additional immunological techniques: immunoblotting, FACS; basics of PCR and hybridization based methods of detection, microarray based detection, multiplexing are newly introduced. Similarly ELISA, Western blotting, Fluorescent Ab test and Hybridoma technique are newly introduced in the practical part.

Course title for BIOCHEM 509 is changed from Food and Nutritional Biochemistry to Nutritional Biochemistry and the course outline is modified to suit the present aspects in nutrition science with inclusion of phytonutrients, prebiotics and probiotics, interrelationship in nutrient functions, mineral deficiency diseases; nutraceuticals, factors affecting bioavailability of nutrients and food sensitivity. New practicals are also introduced.

A new course, Biochemistry on xenobiotics(BIOCHEM511) is proposed considering the pollution from industrial chemicals and waste water leading to heavy metals contamination of the agricultural crops and thebiological and non-biological remediation techniques.

5. Animal Biochemistry (BIOCHEM 508): Agriculture is a multidisciplinary stream and includes animal husbandry. So study of the topics related to animal system will be of immense help for the students.

The Unit–II in the earlier syllabus under BIOCHEM 508 (Animal Biochemistry) is restructured with inclusion of vitamins, energy nutrients, bioactive peptides and functional oligosaccharides with deletion of biochemistry of reproduction from the Unit-III.

Ph. D. courses

There are seven (7) coursesat the Ph. D. level, most of which are of advanced nature. No new course is proposed in the syllabus. Modification of the courses was done as per suggestions from different experts from state agricultural universities and ICAR institutions.

- Units under BIOCHEM 601 (Advanced Enzymology) are redefined with incorporation new topics such as pseudoenzyme and enzyme promiscuity, extremozymes, catalytic nucleic acids (ribozymes, catalytic DNA), immobilization of enzymes, semisynthetic enzymes and their use as industrial biocatalysts and their practical significance, modern information technologies in enzyme engineering.
- In BIOCHEM 602 (Advanced Molecular Biology), the units are redefined with inclusion of several new topics like concept of epigenome, role of histones, riboswitches, genome sequencing technologies, gene silencing technologies, genome editing – TALENs, CRISPR/cas, ZFN and their application and a new unit Aspects of molecular breeding.
- The different units are newly addressed for BIOCHEM 603 (Biochemistry of Biotic and Abiotic Stresses), a course having enormous importance for understanding the interfaring effects of stresses specially with crop growth and development .
- The course title and the credit load for BIOCHEM 604 are changed with new title Frontier topics in biochemistry and with credit load of (2+0). The broad topics for oral presentations to be delivered by the students registering this course are divided into eight major heads.
- The course title for BIOCHEM 605 is changed to Concepts and Application of Omics in Biological Science with fresh inclusion of ionomics part.
- The course title for BIOCHEM 607 is changed to Application of Techniques in Biochemistry. The entire course is divided into five units with Molecular biology and immunochemical techniques in the fifth unit.

Biochemistry courses are offered to a large number of students hence need for a few common types of equipment in multiple numbers cannot be avoided. Moreover, with the advancement of techniques and to cater quality teaching and research, sophisticated equipment like ultra-low freezers, high speed refrigerated- and ultra-centrifuges, automated bioseparation systems like GLC or HPLC, GC-MS, LC-MS; UV-Vis spectrophotometers suitable for enzyme studies, AAS for minerals, PCRs, electrophoresis systems for proteins and DNA are required as essentials in a Biochemistry laboratory. Additional funds may also be required forpurchasing spare parts and for AMC for the instruments. Provisions for training to the teachers to the new areas in the field of Biochemistry and exposure to modern laboratories within and outside the country become a primary need with the changing academic scenario. Moreover, funds may also be required for the proposed exposure visits of the students to other institutes. Financial assistance for these non-recurring and recurring expenses to the tune of a one-time grant of ₹ 5 crores and ₹ 20 lacs per annum respectively, is the need of the time to effectively run Master's and Doctoral programmes in the Discipline of Biochemistry at ICAR-IARI and State Agricultural Universities.

Course Title with Credit Load
M.Sc. (Ag) in Biochemistry

Code Code	Course Title	Credit Hours
BIOCHEM 501*	Basic Biochemistry	3+1
BIOCHEM 502*	Intermediary Metabolism	3+0
BIOCHEM 503*	Enzymology	2+1
BIOCHEM 504	Molecular Biology	2+1
BIOCHEM 505*	Techniques In Biochemistry	2+2
BIOCHEM 506	Immuno Chemistry	2+1
BIOCHEM 507	Plant Biochemistry	2+1
BIOCHEM 508	Animal Biochemistry	3+0
BIOCHEM 509	Nutritional Biochemistry	2+1
BIOCHEM 510	Nitrogen And Sulphur Metabolism	2+1
BIOCHEM 511	Biochemistry On Xenobiotics	2+0
BIOCHEM 591	Master's Seminar	1+0
BIOCHEM 599	Master's Research	30

*Core course

Course Contents
M.Sc. (Ag) in Biochemistry

I. Course Title : Basic Biochemistry

II. Course Code : BIOCHEM 501*

III. Credit Hours : 3+1

IV. Why this course?

To impart the fundamental knowledge on structure and function of cellular components involved in biological processes and an elementary introduction to the study of molecular biology.

V. Aim of the course

The course is designed to provide elementary knowledge/overview of structure and function of proteins, carbohydrates, lipids, nucleic acids and other biomolecules and their metabolism.

No.	Blocks	Units
1.	Introduction to Biochemistry	1. Scope and importance of biochemistry 2. Foundation of life 3. Water 4. Physical techniques for structure determination
2.	Structure and function of biomolecules	1. Biomolecules 2. Immunoglobulins and PR proteins 3. Plant secondary metabolites
3.	Metabolism – the basics	1. Molecules aiding metabolism 2. Thermodynamics –principles and energetic of life
4.	Catabolism and its regulation	1. Catabolism of energy molecules 2. ATP formation
5.	Fundamentals of Molecular biology and genetic engineering	1. Molecular biology processes 2. Recombinant DNA technology

VI. Theory

Block 1: Introduction to Biochemistry

Unit 1: Scope and importance of biochemistry (1 Lecture)

Biochemistry as modern science and its various divisions, Scope and importance of biochemistry in agriculture and allied sciences.

Unit 2: Foundation of life (2 Lectures)

Fundamental principles governing life, supramolecular structures, significance of weak non covalent interactions in biology

Unit 3: Water (3 Lectures)

Structure of water, ionization of water, acid base concept, pH and buffers, significance of structure-function relationship.

Unit 4: Physical techniques for structure determination (2 Lectures)

General introduction to physical techniques for determination of structure of biopolymers.

Block 2: Structure And Function of Biomolecules

Unit 1: Biomolecules (10 Lectures)

Structure, classification, properties and function of carbohydrates, amino acids, proteins, lipids and nucleic acids.

Unit 2: Immunoglobulins and PR proteins (2 Lectures)

Structure, formation and different forms of immunoglobulins, PR proteins and their classification.

Unit 3: Plant secondary metabolites (3 Lectures)

Structure, classification and function of plant secondary metabolites.

Block 3: Metabolism – The Basics

Unit 1: Molecules aiding metabolism (2 Lectures)

Structure and biological functions of vitamins and coenzymes, enzymes: classification and mechanism of action; regulation, factors affecting enzyme action. Hormones: animal and plants.

Unit 2: Thermodynamics –principles and energetic of life (2 Lectures)

Fundamentals of thermodynamic principles applicable to biological processes, Bioenergetics.

Block 4: Catabolism and its Regulation

Unit 1: Catabolism of energy molecules (5 Lectures)

Important and basic degradative metabolic pathways of carbohydrates, lipids and proteins and their regulation.

Unit 2: ATP formation (3 Lectures)

Formation of ATP, substrate level phosphorylation, electron transport chain and oxidative phosphorylation, chemiosmotic theory and proton motive force.

Block 5: Fundamentals of Molecular Biology and Genetic Engineering

Unit 1: Molecular biology processes (4 Lectures)

Overview of replication, transcription and translation.

Unit 2: Recombinant DNA technology (3 Lectures)

Restriction enzymes, DNA cloning, applications of cloning, transgenics.

VII. Practicals

- Preparation of standard and buffer solutions
- Detection of carbohydrates, amino acids and proteins
- Extraction and estimation of sugars
- Extraction and estimation of amino acids
- Extraction and estimation of proteins

- Estimation of acid value of fat/oil
- Estimation of peroxide value of fat/oil
- Estimation of saponification value in fats and oils
- Fatty acid composition in fat/oil by GC
- Estimation of DNA and RNA by spectroscopic methods
- Estimation of Ascorbic acid
- Separation of biomolecules by TLC and Paper chromatography
- Estimation of alpha amylase activity
- Qualitative tests for secondary plant metabolites.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz

IX. Learning outcome

With this course, the students are expected to be able to understand the actual chemical concepts and fundamental processes of biology at molecular level.

X. Suggested Reading

- Nelson DL and Cox MM. 2017. *Lehninger Principles of Biochemistry*. 7th edition. W. H. Freeman & Co Ltd
- Satyanarayana U and Chakrapani U. 2017. *Biochemistry*. 5th edition, Elsevier
- Moran LA, Horton HR, Scrimgeour KG and Perry MD. 2012. *Principles of Biochemistry*. 5th edition Pearson.
- Voet D and Voet JG. 2011. *Biochemistry*. 4th edition John Wiley.
- Pratt CW and Cornely K. 2014. *Essential Biochemistry*. 3rd Edition. Wiley
- Moorthy K. 2007. *Fundamentals of Biochemical Calculations*. 2nd edition. CRC Press
- Conn EE, Stumpf PK, Bruening G and Doi RH. 2006. *Outlines of Biochemistry*. 5th edition. Wiley.

I. Course Title : Intermediary Metabolism

II. Course Code : BIOCHEM 502*

III. Credit Hours : 3+0

IV. Why this course?

To understand the interconversion of chemical compounds in the living system, the pathways taken by individual molecules, their interrelationships and the mechanisms that regulate the flow of metabolites through the pathways.

V. Aim of the course

The course is designed to give an insight into the different metabolic pathways, their interrelationship, regulation, metabolic disorders in human and pathway engineering in plants.

No.	Blocks	Units
1.	Introduction to metabolism	1. Overview of metabolism 2. Metabolic pathways
2.	Metabolism of energy nutrients	1. Carbohydrate metabolism

No.	Blocks	Units
		2. Lipid metabolism 3. Protein metabolism 4. Energy transduction and oxidative phosphorylation
3.	Sulphur and nucleotide metabolism	1. Sulphur metabolism 2. Nucleotide metabolism
4.	Metabolic regulation and defects in metabolism	1. Regulation of metabolic pathways 2. Defects in metabolism

VI. Theory

Block 1: Introduction To Metabolism

Unit 1: Overview of metabolism (4 Lectures)

The living cell - a unique chemical system, biochemical reaction types, bioenergetics, bioavailability of nutrients, transport mechanism, signal transduction.

Unit 2: Metabolic pathways (5 Lectures)

Catabolism and anabolism, compartments of metabolic pathways, experimental approaches to study metabolism, metabolic profiles of major organs.

Block 2: Metabolism of Energy Nutrients

Unit 1: Carbohydrate metabolism (5 Lectures)

Major catabolic and anabolic pathways of carbohydrate metabolism, the glyoxylate pathway.

Unit 2: Lipid metabolism (5 Lectures)

Fatty acid oxidation, ketone bodies, fatty acid biosynthesis, synthesis of triacylglycerols, cholesterol, eicosanoids.

Unit 3: Protein metabolism (3 Lectures)

General reactions of amino acid metabolism, degradative and biosynthetic pathways of amino acids, urea cycle, amino acids as metabolic precursors.

Unit 4: Energy transduction and oxidative phosphorylation (4 Lectures)

Mechanisms of energy transduction, electron transport system, oxidative phosphorylation, control of ATP production.

Block 3.sulphur and Nucleotide Metabolism

Unit 1: Sulphur metabolism (5 Lectures)

Sulphate reduction and incorporation of sulphur in to amino acids.

Unit 2: Nucleotide metabolism (3 Lectures)

Synthesis and degradation of purine and pyrimidine nucleotides.

Block 4: Metabolic Regulation and Defects in Metabolism

Unit 1: Regulation of metabolic pathways (4 Lectures)

Regulation of carbohydrate, lipid, protein, nucleotide metabolism and oxidative phosphorylation.

Unit 2: Defects in metabolism (4 Lectures)

Disorders of carbohydrates, lipids, amino acids and nucleic acid metabolism, and inborn errors of metabolism. Metabolic pathway engineering.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

With this course, the students are expected to learn the set of life-sustaining chemical processes that enables organisms transform the chemical energy stored in molecules into useful form and the process by which organisms respond to stimuli and metabolic disorders.

IX. Suggested Reading

- Nelson, D. L. and Cox, M. M. 2017. *Lehninger Principles of Biochemistry*. 7th edition. W. H. Freeman & Co Ltd
- Satyanarayana, U. and Chakrapani, U. 2017. *Biochemistry*. 5th edition, Elsevier
- Campbell M. K. and Farrell S.O. 2009. *Biochemistry*. 6thedition Thomson Higher Education.
- Moran L. A., Horton H. R., Scrimgeour K. G. and Perry, M. D. 2012. *Principles of Biochemistry*. 5th edition Pearson,
- Voet, D. and Voet J. G. 2011. *Biochemistry*. 4thedition . John Wiley.
- Pratt, C. W. and Cornely, K. 2014. *Essential Biochemistry*. 3rd Edition. Wiley
- Moorthy, K. 2007. *Fundamentals of Biochemical Calculations*. 2nd edition. CRC Press

I. Course Title : Enzymology

II. Course Code : BIOCHEM 503*

III. Credit Hours : 2+1

IV. Why this course?

Being highly specific and incredibly efficient biological catalysts, enzymes are responsible for bringing about almost all of the chemical reactions in living organisms. Otherwise these reactions will take place at a rate far too slow for the pace of metabolism. The course will help students in understanding the physical, chemical and kinetic properties of enzymes.

V. Aim of the course

To impart knowledge about the catalytic role of enzymes, their structure, physico-chemical, kinetic and regulatory properties and mechanism of action.

No.	Blocks	Units
1.	Introduction to enzymes	1. Structure and function of enzyme 2. Extraction and purification of enzymes
2.	Enzyme structure and function	1. Chemical nature of enzyme 2. Cofactors and coenzymes 3. Nature of active site
3.	Enzyme kinetics	1. Single substrate kinetics 2. Enzyme inhibition 3. Kinetics of allosteric enzymes

No.	Blocks	Units
		4. Regulation of enzyme activity
4.	Application of enzymology	1. Industrial application of enzymes 2. Biotechnological application of enzymes

VI. Theory

Block 1: Introduction To Enzymes

Unit 1: Structure and function of enzyme (2 Lectures)

Historic perspective, general properties of enzymes, enzyme compartmentalization in cell organelles, nomenclature and classification of enzymes, ribozymes, isozymes, abzymes.

Unit 2: Extraction and purification of enzymes (2 Lectures)

Extraction of soluble and membrane-bound enzymes, purification of enzymes, measurement of enzyme activity.

Block 2: Enzyme Structure and Function

Unit 1: Chemical nature of enzyme (3 Lectures)

Enzyme specificity, monomeric and oligomeric enzymes, catalytic mechanism, mechanism of enzyme action, pseudoenzymes, enzyme promiscuity.

Unit 2: Cofactors and coenzymes (2 Lectures)

Chemical nature and involvement of cofactors and coenzymes in enzyme catalyzed reactions, metal activated enzymes and metalloenzymes, mechanism of enzyme catalyzed reactions without cofactors.

Unit 3: Nature of active site (2 Lectures)

Active site, identification of binding sites and catalytic sites.

Block 3. Enzyme Kinetics

Unit 1: Single substrate kinetics (4 Lectures)

Relationship between initial velocity and substrate concentration, Michaelis-Menten equation, Lineweaver-Burk and Eadie-Hofstee plots, analysis of kinetic data, numerical exercises.

Unit 2: Enzyme inhibition (2 Lectures)

Reversible and irreversible enzyme inhibition, uses of enzyme inhibition.

Unit 3: Kinetics of allosteric enzymes (3 Lectures)

Nature of allosteric enzymes, sigmoidal kinetics, MWC model and allosteric regulation, KNF model and allosteric regulation.

Unit 4: Regulation of enzyme activity (3 Lectures)

Feedback regulation, regulatory enzymes, control of enzymatic activity, symmetry and sequential model, reversible covalent modification of enzymes.

Block 4: Application of Enzymology

Unit 1: Industrial application of enzymes (3 Lectures)

Industrial application of enzyme catalysis in sectors like food processing, detergents, biofuels, paper and pulp, biosensors and clinical applications of enzymes.

Unit 2: Biotechnological application of enzymes (2 Lectures)

Large scale production and purification of enzymes, immobilization of enzymes.

VII. Practicals

- Soluble protein estimation
- Enzyme assay by taking any model enzyme
- Isolation and purification of any model enzyme
- Study of the effect of enzyme and substrate concentrations on enzyme activity
- Determination of K_m and V_{max}
- Determination of pH and temperature optima
- Effect of inhibitors on enzyme activity
- Determination of pH and temperature stability of enzyme
- Electrophoretic analysis of isozymes.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the chemical principles of enzyme catalysis, action of enzymes as biocatalysts and factors that influence enzyme activity and understand the kinetics of enzymatic reactions. Students will have experience with purification, handling and characterization of proteins and also get exposure of wide applications of enzymes and their future potential.

X. Suggested Reading

- Palmer T and Bonner PL. 2007. *Enzymes: Biochemistry, Biotechnology, Clinical Chemistry*. 2nd edition. Woodhead Publishing
- Okotore RO. 2015. *Essentials of Enzymology*. XLIBRIS
- Herald J. 2016. *Essentials of Enzymology*. Syrawood Publishing House
- Suzuki, H. 2015. *How Enzymes Work: From Structure to Function*. Jenny Stanford Publishing.
- Bugg TDH. 2012. *Introduction to Enzyme and Coenzyme Chemistry*, 3rd Edition. WILEY
- Guo Y. 2014. *Enzyme Engineering*. Science Press
- Bisswanger H. 2011. *Practical Enzymology*. Wiley-Blackwell

I. Course Title : Molecular Biology

II. Course Code : BIOCHEM 504

III. Credit Hours : 2+1

IV. Why this course?

Molecular biology is the study of biology at a molecular level. The concepts and techniques of molecular biology are the foundation for the studies of all aspects of biology in modern time. This course is designed to provide an intensive exposure to the theoretical concepts and experimental techniques of molecular biology and the interrelationship of DNA, RNA and protein synthesis and their regulation.

V. Aim of the course

To provide knowledge of life processes at the molecular and cellular levels, including the storage, transfer and regulation of genetic information and specialist theoretical knowledge and practical experience of gene manipulation and the analysis of nucleic acids and proteins.

No.	Blocks	Units
1.	Introduction to nucleic acids	1. History 2. Properties of nucleic acid 3. Genes and genome
2.	Synthesis of nucleic acids	1. DNA replication 2. Transcription
3.	Protein synthesis	1. Translation machinery 2. Mechanism of protein synthesis 3. Post-translational events
4.	Gene manipulation	1. DNA sequencing 2. Recombinant DNA technology 3. Techniques in molecular biology

VI. Theory

Block 1: Introduction to Nucleic Acids

Unit 1: History (1 Lecture)

Historical development of molecular biology, nucleic acids as genetic material.

Unit 2: Properties of nucleic acid (2 Lectures)

Nucleic acid structure, chemical and physical properties of nucleic acids, spectroscopic and thermal properties of nucleic acids, DNA supercoiling.

Unit 3: Genes and genome (3 Lectures)

Concept of genes and genome,genome complexity, genome organization in prokaryotes and eukaryotes, chromatin structure and function, repetitive and non-repetitive DNA, satellite DNA central dogma, genome editing.

Block 2: Synthesis of Nucleic Acid

Unit 1: DNA replication (3 Lectures)

Modes of replication, DNA polymerases, topoisomerases, DNA ligase, model of replisome, semi conservative replication in prokaryotes and eukaryotes, inhibitors of replication, DNA damage and repair.

Unit 2: Transcription (3 Lectures)

Basic principles of transcription, transcription initiation, elongation and termination, RNA processing, RNA interference, siRNAs, miRNAs and other ncRNAs, DNA/RNA editing. regulation of transcription, reverse transcription.

Block 3. Protein Synthesis

Unit 1: Translation machinery (2 Lectures)

Ribosomes structure and function, organization of ribosomal proteins and RNA genes, genetic code, aminoacyl tRNA synthases.

Unit 2: Mechanism of protein synthesis (2 Lectures)

Initiation, chain elongation and termination of translation, energetics, inhibitors of translation.

Unit 3: Post-translational events (2 Lectures)

Post translational modifications of nascent polypeptide, protein targeting and turnover, regulation of gene expression in prokaryotes and eukaryotes, nucleases and restriction enzymes.

Block 4: Gene Manipulation

Unit 1: DNA sequencing (3 Lectures)

Importance, Sanger method,High-Throughput Sequencing (HTS) techniques, applications of DNA sequencing.

Unit 2: Recombinant DNA technology (4 Lectures)

Vectors, isolation of genes, recombinants vector, selection of recombinants, characterization and expression of cloned DNA, transformation, transgenesis, mutation, molecular mechanism of mutation, site directed mutagenesis, *in vitro* mutagenesis.

Unit 3: Techniques in molecular biology (3 Lectures)

Polymerase chain reaction (PCR), expression cloning, gel electrophoresis, molecular markers, macromolecule blotting and probing, arrays (DNA array and protein array) – principles and application.

VII. Practicals

- Isolation and purification of DNA and RNA
- To check the purity of isolated DNA and RNA
- Restriction fragmentation of genomic DNA
- Separation of oligos by agarose gel electrophoresis
- Southern blotting experiments
- Northern blotting experiments
- Cloning of DNA fragment in vector
- Selection of recombinant
- SSR analysis of DNA
- cDNA synthesis using RT- PCR
- Basic tools in bioinformatics analysis

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

After completion, the student should be able to explain central cell biological processes and how they are regulated and quality assured and understands how molecular cell biology forms the foundation of biotechnology.

X. Suggested Reading

- Snape A, Papachristodoulou D, Elliott, W. H. and Elliott, C. 2014. *Biochemistry and Molecular*

Biology. Oxford University Press.
- Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. 2018. *Lewin's GENES XII*. Jones & Bartlett Learning.
- Lodish, H.,Berk, A., Kaiser, C. A., Krieger, M. And Bretscher, A. 2016. *Molecular Cell Biology*.W H Freeman & Co.
- Hoffmann, A. And Clokie, S. 2018. *Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology*. Cambridge University Press.
- Primrose SB, Twyman RM and Old RW.2002. *Principles of Gene Manipulation*: 6th Ed. Wiley
- Karp, G. 2013. *Cell and Molecular Biology*. Wiley.
- Neidle, S. 2008. *Principles of Nucleic Acid Structure*. Elsevier Inc.
- Watson J, Baker TA, Bell SP, Gann A, Levine M and Losick, R. 2014. *Molecular biology of the gene* 7th edition, Pearson.

I. Course Title : Techniques in Biochemistry

II. Course Code : BIOCHEM 505*

III. Credit Hours : 2+2

IV. Why this course?

Biochemical studies rely on the availability of appropriate analytical techniques and their applications. This course will examine modern methods and technologies that are used in biochemical analysis with emphasis on instrumentation, underlying principles, aims, strategies and current applications.

V. Aim of the course

To provide hands-on experience to different biochemical techniques commonly used in research along with the knowledge on principles and the instrumentation.

No.	Blocks	Units
1.	Separation techniques	1. Chromatography techniques 2. Electrophoretic technique 3. Hydrodynamic methods 4. Centrifugation
2.	Spectroscopic techniques	1. Spectrophotometry 2. Mass spectroscopy 3. Atomic absorption spectrophotometry
3.	Microscopy	1. Microscopic techniques
4.	Tracer, imaging, immunochemical and other techniques	1. Tracer techniques 2. Imaging techniques 3. Immunochemical techniques 4. Other techniques

VI. Theory

Block 1: Separation Techniques

Principles and applications of separation techniques.

Unit 1: Chromatography techniques (4 Lectures)

Principles and applications of paper, thin layer, gel filtration, ion-exchange, affinity, column & HPTLC, GC, HPLC and FPLC.

Unit 2: Electrophoretic technique (2 Lectures)

General principles,paper and gel electrophoresis, native and SDS-PAGE, 2D-PAGE, capillary electrophoresis.

Unit 3: Hydrodynamic methods (2 Lectures)

Hydrodyanmic methods of separation of biomolecules such as viscosity and sedimentation velocity, - their principles.

Unit 4: Centrifugation (2 Lectures)

Basic principles of sedimentation, type, care and safety aspects of centrifuge preparative and analytical centrifugation.

Block 2: Spectroscopic Techniques

Unit 1: Spectrophotometry (3 Lectures)

Principles and applications of UV-visible, Fluorescence, IR and FTIR, Raman, NMR and FTNMR, ESR and X-Ray spectroscopy.

Unit 2: Mass spectroscopy (3 Lectures)

MS/MS, LC-MS, GC-MS, MALDI-TOF, applications of mass spectrometry in biochemistry.

Unit 3: Atomic absorption spectrophotometry (2 Lectures)

Principle, function and instrumentation ofatomic absorption spectrophotometry.

Block 3. Microscopy

Unit 1: Microscopic techniques (2 Lectures)

Principles and applications, light, UV, phase contrast, fluorescence and electron microscopy, flow cytometry.

Block 4: Tracer, Imaging, Immunochemical and Other Techniques

Unit 1: Tracer technique (2 Lectures)

Tracer techniques in biology: concept of radioactivity, radioactivity counting methods with principles of different types of counters, concept of á, â and ã emitters, scintillation counters, γ-ray spectrometers, autoradiography, applications of radioactive tracers in biology.

Unit 2: Imaging techniques (2 Lectures)

Principles and applications of phosphor imager, MRI and CT scan.

Unit 3: Immunochemical technique (2 Lectures)

Production of antibodies, immunoprecipitation, immunoblotting, immunoassays, RIA and ELISA.

Unit 4: Other techniques (2 Lectures)

Cryopreservation, polymerase chain reaction (PCR), FACS.

VII. Practicals

- Expression of concentration in terms of dilution, molarity, normality, percent expression
- pH measurement and buffer preparation
- Determination of absorption maxima of biomolecules

- Estimation of biomolecules through spectrophotometry and other methods
- Separation of carbohydrates and amino acids by paper chromatography
- Separation and analysis of fatty acids/lipids by GC
- Separation/estimation of biomolecules through HPLC and FPLC
- Separation of proteins using ion exchange, gel filtration and affinity chromatography
- Electrophoretic separation of proteins and nucleic acids
- Centrifugation- differential and density gradient
- $(NH_4)_2SO_4$ precipitation and dialysis
- Use of radioisotopes in metabolic studies
- PCR
- ELISA
- Western blotting/ Dot blotting

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

At the end of the course, the student will acquire the basic knowledge of the main biochemical methods used in the separation, identification, characterization and analysis of biomolecules.

X. Suggested Reading

- Boyer R. 2011. *Biochemistry Laboratory: Modern Theory and Techniques* 2nd Edition. Pearson
- Hofmann A and Clokie S. 2010. *Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology*. 7th edition. Cambridge University Press.
- Sawhney SK and Singh R. 2000. *Introductory Practical Biochemistry*. 2nd Ed. Narosa
- Katoch R. 2011. *Analytical Techniques in Biochemistry and Molecular Biology*. Springer
- Boyer R. 2009. *Modern Experimental Biochemistry*. Fifth impression. Pearson
- Lottspeich F and Engels JW. (Eds). 2018. *Bioanalytics: Analytical Methods and Concepts in Biochemistry and Molecular Biology*. Wiley-VCH
- Wilson K and Walker J. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*, 7th Edition. Cambridge University Press

I. Course Title : Immunochemistry

II. Course Code : BIOCHEM 506

III. Credit Hours : 2+1

IV. Why this course?

This is an introduction to the field of immunology with emphasis on the biochemical aspects of the systems. This course is intended to equip the student with the knowledge and understanding of the vertebrate immune system, its component and mechanism of immune responses with specific reference to the human immune defence system and plant immunity

V. Aim of the course

To give an insight into the biochemical basis of immunity

No.	Blocks	Units
1.	Basics of Immunology	1. Introduction to immunology 2. Antibodies 3. The immune responses 4. Immunoregulation and immunological techniques

VI. Theory

Block 1: Basics of immunology

Unit 1: Introduction to immunology (7 Lectures)

History and scope of immunology, antigens, adjuvants, immune system, organs, tissues and cells, immunoglobulins, molecular organization of immunoglobulin. Haptens, ag-ab interaction, plant immunity, proteasome mediated process, plantibodies

Unit 2: Antibodies (5 Lectures)

Classes of antibodies, antibody diversity, theories of generation of antibody diversity, vaccine, monoclonal and polyclonal antibodies, hybridoma, recombinant antibodies, complement system - classical and alternate.

Unit 3: The immune responses (8 Lectures)

Cellular interactions in immune response, major histocompatibility complex, cell mediated immune response, cytokines.

Unit 4: Immunoregulation and immunological techniques (8 Lectures)

Immunoregulation, immunological tolerance, hypersensitivity, mechanisms of immunity, innate resistance and specific immunity, current immunological techniques – elisa, ria, immunoblotting, facs; basics of pcr and hybridization based methods of detection, microarray based detection, multiplexing.

VII. Practicals

- Handling, inoculation and bleeding of laboratory animals
- Preparation of antigens and antisera, natural antibodies
- Carbon clearance test
- Lymphoid organs of the mouse
- Morphology of the blood leucocytes
- Separation of lymphocytes from blood, viable lymphocyte count
- Antigen-antibody interaction,
- Precipitation and agglutination
- Direct and indirect haemagglutination
- Immunoelectrophoresis
- Complement fixation
- Quantitation of immunoglobulins by zinc sulphate turbidity and single radial immunodiffusion
- ELISA
- Western blotting
- Fluorescent Ab test
- Hybridoma technique

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

It is expected that the student should understand and explain the structure, functioning and importance of human immune system in term of health and disease.

Suggested Reading

- Punt J, Stranford S, Jones P and Owen J. 2018 . Kuby Immunology. 8th edition. W. H. Freeman
- Renshaw S. 2016. *Immunohistochemistry and Immunocytochemistry: Essential Methods*, 2nd Edition. John Wiley & Sons, Ltd.
- Abbas AK, Lichtma AH and Pillai S. 2018. *Cellular and Molecular Immunology*. 9th edition. Elsevier
- Delves PJ, Martin SJ, Burton DR and Roitt IM. 2017. *Roitt's Essential Immunology*, 13th Edition. Wiley-Blackwell

I. Course Title : Plant Biochemistry

II. Course Code : BIOCHEM 507

III. Credit Hours : 2+1

IV. Why this course?

Harnessing sunlight, plants produce a diverse array of chemical compounds to survive in challenging ecological niches. Plant-derived metabolites are major sources of human food, fibre, fuel, and medicine. This course covers topics related to plant metabolism and discusses how plants generate carbon and energy sources by photosynthesis and synthesize various compounds through complex networks of metabolic pathways.

V. Aim of the course

To provide an understanding of metabolic processes in plants and the role of different biosynthetic pathways in plant growth and development.

No.	Blocks	Units
1.	Photosynthesis	1. Photosynthetic machinery 2. Carbon reduction
2.	Conversion of photosynthates	1. Synthesis of major biomolecules 2. Nitrogen and sulphur metabolism
3.	Growth and development	1. Germination and fruit ripening 2. Phytohormones
4.	Secondary metabolites	1. Biochemistry of plant secondary metabolites

VI. Theory

Block 1: Photosynthesis

Unit 1: Photosynthetic machinery (3 Lectures)

Structure and function of plant cell and its organelles, phytochromes, chloroplast morphology structure, structure and chemistry of photosynthetic pigments, light reaction of photosynthesis.

Unit 2: Photosynthesis – the process (4 Lectures)

Carbon reduction in C_3, C_4 and CAM plants, photorespiration, sucrose-starch interconversion.

Block 2: Conversion of Photosynthates

Unit 1: Synthesis of major biomolecules (3 Lectures)

Biosynthesis of structural carbohydrates, storage proteins and lipids.

Unit 2: Nitrogen and sulphur metabolism (5 Lectures)

Basic concepts of nitrogen and sulphur metabolism: biological nitrogen fixation, nitrate assimilation in plants, sulphur chemistry and function, reductive sulphate assimilation pathway, sulphated compounds.

Block 3: Growth and Develpoment

Unit 1: Germination and fruit ripening (4 Lectures)

Biochemistry of seed germination – stages, requirements, metabolism and mobilization of storage material; Biochemistry of fruit ripening – ripening process, cell wall degrading enzymes, role of ethylene and regulation of ethylene production.

Unit 2: Phytohormones (3 Lectures)

Different classes of phytohormones, their biosynthesis and mode of action.

Block 4: Secondary Metabolites

Unit 1: Biochemistry of plant secondary metabolites (6 Lectures)

Biochemistry and significance of plant secondary metabolites – phenolics, terpenoids, alkaloids, cyanogenic glycosides and glucosinolates, effect of biotic and abiotic factors on plant metabolism and plant defense system.

VII. Practicals

- Fractionation of cell organelles,
- Estimation of starch,
- Assay of ADPG pyrophosphorylase/starch synthase,
- Assay of PAL/SOD
- Assay of PPO/LOX,
- Estimation of individual amino acids,
- Qualitative tests of secondary metabolites (alkaloids, sterols etc.)
- Content and composition of carotenoids, anthocyanin and chlorophylls
- Determination of polyphenols/phenolics
- Fractionation of storage proteins
- Estimation of glucosinolates
- Estimation of cyanogenic compounds.

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

Successful completion of this course will provide students with fundamental knowledge of biochemistry and specific knowledge of compounds and biochemical pathways that occur in plants.

X. Suggested Reading

- Buchannan BB, Gruissem W and Jones R.L. (eds.). 2000. *Biochemistry and Molecular Biology of Plants.* 2nd edition. WILEY Blackwell
- Heldt, H-W. 2010. *Plant Biochemistry and Molecular Biology*. 4th ed. Oxford University Press
- Goodwin TW and Mercer EI. 2005. *Introduction to Plant Biochemistry*. 2nd edition. CBS
- Heldt, H-W. and Piechulla, B. 2010.*Plant Biochemistry*. 4th Edition. Elsevier
- Harinda, Makkeaand Klaus. 2007. *Plant Secondary Metabolites.* Springer
- Cseke LJ, Kirakosyan A, Kaufman PB, Warber S, Duke JA, Brielmann HL. 2006. *Natural Products from Plants*. 2ndEdition. CRC Press

I. Course Title : Animal Biochemistry

II. Course Code : BIOCHEM 508

III. Credit Hours : 3+0

IV. Why this Course?

Biochemistry is one of the few basic sciences where animal and plant kingdoms meet. It provides the knowledge base for all human and animal health studies. Knowledge of biochemistry will enable one to study, or to pursue a line of research in applied sciences.

V. Aim of the Course

To impart knowledge regarding biochemistry of various physiological processes, specialized tissues and hormone action in animal system

No.	Blocks	Units
1.	Animal biochemistry	1. Biochemistry of assimilation 2. Nutrients and their biochemistry 3. Hormones and their role 4. Immune system

VI. Theory

Block 1: Animal Biochemistry

Unit 1: Biochemistry of assimilation (7 Lectures)

Digestion and absorption of food, Detoxification, biochemistry of specialized tissues – connective tissue, skin, muscle, nervous tissue and blood and other body fluids.

Unit 2: Nutrients and their biochemistry (7 Lectures)

Water, electrolyte and acid-base balance, structure, function and mechanism of major trace elements, vitamins, energy nutrients and biochemistry of respiration, bioactive peptides and functional oligosaccharides.

Unit 3: Hormones and their role (7 Lectures)

Hormones of thyroid, hypothalamus, pituitary, pancreas, adrenals and sex hormones, Membrane receptors of hormones, signal transduction.

Unit 4: Immune system (7 Lectures)

Immune systems, immunoglobulins, monoclonal antibodies, formation of antibody, antibody diversity, complement system – classical and alternate, major histocompatibility complexes, cell mediated immune response, mechanisms of immunity.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

Students can acquire essential foundation knowledge for further study in life sciences, agriculture, environmental science, health science, etc.

IX. Suggested Reading

- Bradley, A. 2018. Animal Physiology and Biochemistry. 1st edition. Edtech Press
- Agarwal RA, Srivastava, A.K. and Kumar, K. 2010. *Animal Physiology and Biochemistry*. Fifth revised edition S. Chand.
- Rodwell VA, Bender DA, Botham KM, Kennelly PJ and Weil PA. 2018. *Harper's Illustrated Biochemistry*, 31st edition. McGraw-Hill Education.

I. Course Title : Nutritional Biochemistry

II. Course Code : BIOCHEM 509

III. Credit Hours : 2+1

IV. Why this course?

Nutritional biochemistry deals with the structural and functional characteristics of macro and micronutrients in food consumed by humans. The course will expand understanding of the biological roles of nutrients and their metabolism using basic knowledge in physiology, biochemistry, cell biology and molecular biology. It will integrate information on the roles of nutrients in nutrition and health.

V. Aim of the course

To impart knowledge regarding the biochemical aspects of various nutrients and their interactions in foods during processing, storage and deterioration.

No.	Blocks	Units
1.	Nutritional biochemistry	1. Fundamentals of human nutrition 2. Biochemical functions of nutrients 3. Bioavailability of nutrients 4. Food sensitivity

VI. Theory

Block 1: Nutritional Biochemistry

Unit 1: Fundamentals of human nutrition (7 Lectures)

Fundamentals of human nutrition, concept of balanced diet, biochemical composition, energy and food value of various food grains (including cereals, pulses, oilseeds), fruits and vegetables. Physico-chemical, functional and nutritional characteristics of carbohydrates, proteins and fats and their interactions (emulsions, gelation, browning etc.). Digestion and absorption, digestive secretions, their characteristic features and control, protection of microflora of the GI tract

Unit 2: Biochemical functions of nutrients (7 Lectures)

Biochemical functions of nutrients, macro- and micronutrients- carbohydrates, fats and proteins, vitamins, water soluble and fat soluble vitamins, mineral and phytonutrients, prebiotics and probiotics, enzymes and metabolic protein factors, cofactor role, electrolytic function, constituents of skeletal tissues, interrelationship in nutrient functions, mineral deficiency diseases; nutraceuticals, antinutritional factors, biochemistry of postharvest storage.

Unit 3: Bioavailability of nutrients (7 Lectures)

Factors affecting bioavailability of nutrients, biological value of proteins; effect of cooking, processing and preservation of different food products on nutrients, energy- and micronutrient malnutrition, deficiency diseases of macro and micronutrients.

Unit 4: Food sensitivity (7 Lectures)

Food sensitivity: immunologically mediated food sensitivity, nature and properties of antigens in foods, mechanism of induction of all allergic reactions, diagnostic tests for food, hypersensitivity, non-immunologically mediated food sensitivity, food sensitivity due to metabolic diseases, gastrointestinal diseases, food additives, pharmacologic agents, food toxins and poisonous and psychological factors.

VII. Practicals

- Estimation of amylose and amylopectin
- Estimation of resistant starch
- Estimation of ù3, ù6 and trans fatty acid
- Estimation of phenols in plant tissue/sample
- Estimation of carotenoids
- Estimation of amylase, trypsin and chymotrypsin inhibitor activities
- Estimation of Vitamin C in fruits
- Estimation of reducing & non reducing sugar in fruits
- Estimation of protein contents
- Estimation of dietary fibre
- Determination of limiting amino acids
- Estimation of phytate/ oxalate
- Estimation of total antioxidant activity by different methods
- Estimation of curcumin.

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

On successful completion of this course students should be able to critically analyse and evaluate concepts in nutritional biochemistry that are important for an understanding of human nutrition, provide nutritional advice based on sound scientific findings, discuss the efficacy and appropriate use of functional foods and critically evaluate nutrition information appearing in popular magazines and other forms of media.

X. Suggested Reading

- Damodaran S. and Parkin KL (ed.) 2017. *Fennema's Food Chemistry*. CRC Press
- Gibney MJ, Lanham-New SA, Cassidy, A and Voster HH (ed.) 2009. *Introduction to Human Nutrition*. Wiley-Blackwell
- Trueman, P. 2007. *Nutritional Biochemistry*. MJP Publishers
- Cox, C. 2015.*Nutritional Biochemistry: Current Topics in Nutrition Research*. Apple Academic Press Inc.
- Haugen, S. and Meijer, S. 2010. *Handbook of Nutritional Biochemistry: Genomics, Metabolomics & Food Supply*. Nova Science Publishers Inc.

I. Course Title : Nitrogen and Sulfur Metabolism

II. Course Code : BIOCHEM 510

III. Credit Hours : 2+1

IV. Why this course?

Nitrogen and sulfur compounds are continuously synthetized, degraded and converted into other forms in nature. They coexist in the biosphere as free elements or in the form of oxyanions which are to be reduced before undergoing anabolic processes to form N and S containing compounds. This course will provide the students a fundamental understanding of their reduction, assimilation and metabolism in plants.

V. Aim of the course

To impart knowledge of general nitrogen and sulfur metabolism in plants and the assimilatory pathways.

No.	Blocks	Units
1.	Nitrogen and sulfur metabolism	1. Nitrogen metabolism 2. Sulfur metabolism

VI. Theory

Block 1: Nitrogen and Sulfur Metabolism

Unit 1: Nitrogen metabolism (18 Lectures)

Nitrogen cycle, assimilation of inorganic nitrogen, nitrate uptake and transporters, enzymology of nitrate reduction - Nitrate reductase (NR) and Nitrite reductase (NiR), NR regulation, nitrate signaling.

Assimilation of inorganic nitrogen and N-transport amino acids - glutamine synthetase (GS), glutamate synthase (GOGAT), glutamate dehydrogenase (GDH), aspartate amino transferase (AspT) and asparagine synthetase (AS), interaction between carbon metabolism and amino acid synthesis, biosynthesis of amino acids. Nitrogen fixation - an overview, enzymology of nitrogen fixation - nitrogenase, *nif* genes and their regulation, symbiotic nitrogen fixation - biochemical basis of rhizobial infection, nodule development. Mechanism of creation of microaerobic environment for nitrogen fixation. metabolic exchange between host plant and bacteroids.

Unit 2: Sulphur metabolism (10 Lectures)

Overview of sulfate assimilation, sulfur chemistry and function, sulfate uptake and transport, reductive sulfate assimilation pathway, synthesis and function of sulfur containing amino acids, glutathione and its derivatives, role of sulfated compounds in metabolism.

VII. Practicals

- Estimation of nitrite content,
- Estimation of nitrate content,
- *In vivo* assay of nitrate reductase activity,
- *In vitro* assay of nitrate reductase activity,
- *In vitro* assay of nitrite reductase activity,
- *In vitro* assay of glutamine synthetase activity,
- *In vitro* assay of glutamate synthase and glutamate dehydrogenase activity,
- Estimation of ureides and amides,
- Assay of nitrogenase activity by acetylene reduction method,
- Estimation of hydrogen evolution by legume nodules,
- Estimation of cysteine, methionine, pyruvate and glutathione,
- Assay of APS activity.

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

Students will get an insight into the nitrogen and sulfur metabolism in plants and the coordination between nitrogen (N) and sulfur (S) assimilation

X. Suggested Reading

- Bothe, H. and Trebst, A. (eds.). 1981. *Biology of Inorganic Nitrogen and Sulfur*. Conference proceedings. Springer-Verlag
- De Kok *et al*. 2012. *Sulfur Metabolism in Plants*. Part of the Proceedings of the International Plant Sulfur Workshop book series. Springer
- Bray CM. 1983. *Nitrogen Metabolism in Plants*. Longman.
- Bidwell, R.G.S. 1983. *Plant Physiology: A Treatise*, Vol. 8: Nitrogen Metabolism. Academic Press
- Foyer. C. H. and Zhang, H. 2010. *Nitrogen Metabolism in Plants in the Post-Genomic Era.* Annual Plant Reviews, Vol.42. Wiley-Blackwell
- Buchanan B.B., Gruissem W. and James R. L. (Eds.). 2000. *Biochemistry and Molecular Biology of Plants*. American Society of Plant Physiologists.

I. Course Title : Biochemistry on Xenobiotics

II. Course Code : BIOCHEM 511

III. Credit Hours : 2+0

IV. Why this course?

Xenobiotics are compounds that are foreign to an organism that include compounds like drugs, food additives, and environmental pollutants. Knowledge on metabolic conversion of xenobiotics, especially drugs and environmental contaminants in living system becomes pertinent in present day scenario with increased levels of pollution.

V. Aim of the course

To impart knowledge on xenobiotics and the mechanism of their metabolism and detoxification in living system.

No.	Blocks	Units
1.	Biochemistry on xenobiotics	1. Xenobiotics 2. Mode of degradation 3. Plant metabolism of xenobiotics 4. Phytoremediation

VI. Theory

Block 1: Biochemistry on Xenobiotics

Unit 1: Xenobiotics (7 Lectures)

Xenobiotics: classification and their effects on biological systems, Problems related to xenobiotics degradation, potential effects of toxic agents on immune system function, biotic metabolism of xenobiotics - biodegradation/biotransformation

Unit 2: Mode of degradation (7 Lectures)

Mode of degradation - Enzymatic and Non-enzymatic, Metabolism of toxic compounds with reference to role of detoxifying enzymes, Mechanism of xenobiotics detoxification - in animal using the enzymes of Phase I and Phase II, Role of microbes in xenobiotics degradation and co-metabolism, Biodegradation and its genetics, manipulation of xenobiotic degradative genes

Unit 3: Plant metabolism of xenobiotics (7 Lectures)

Plant metabolism of xenobiotics - transformation, conjugation and compartmentation, Metabolic responses of pesticides in plants, Impact, metabolism, and toxicity of heavy metals in plants, Regulation of xenobiotics in higher plants: signalling and detoxification.

Unit 4: Phytoremediation (7 Lectures)

Phytoremediation, Advances in development of transgenic plants for remediation of xenobiotic pollutants, safety assessment of xenobiotics

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

Students will gain the basic knowledge and perspectives of bioelimination of xenobiotic compounds.

IX. Suggested Reading

- Richardson, M. 1996. *Environmental Xenobiotics*. CRC Press
- Singh, A., Prasad, S.M. and Singh, R.P.(eds). 2016. *Plant Responses to Xenobiotics*. Springer.
- Chang, Y-C. (ed). 2019. *Microbial Biodegradation of Xenobiotic Compounds*. CRC Press
- Costas Ioannides (ed). 2002. Enzyme Systems that Metabolise Drugs and Other Xenobiotics. Wiley
- Lee, P., Aizawa, H., Gan, L., Prakash, C. And Zhong, D. 2014. *Handbook of Metabolic Pathways of Xenobiotics*. –
- Emerson, M.L. 2012. Xenobiotics*: New Research*. Nova Science
- Shamaan, N.A. 2008. *Biochemistry of xenobiotics: towards a healty lifestyle and safe environment.* PenerbitUniversiti Putra Malaysia.

Course Title with Credit Load
Ph.D. in Biochemistry

Course Code	Course Title	Credit Hours
BIOCHEM 601*	Advanced Enzymology	2+1
BIOCHEM 602	Advanced Molecular Biology	3+0
BIOCHEM 603	Biochemistry Of Biotic And Abiotic Stresses	3+0
BIOCHEM 604	Frontier Topics In Biochemistry	2+0
BIOCHEM 605	Concepts And Aplication Of Omics In Biological Science	3+0
BIOCHEM 606	Biomembranes	2+0
BIOCHEM 607*	Application Of Techniques In Biochemistry	1+2
BIOCHEM 691	Doctoral Seminar I	1+0
BIOCHEM 692	Doctoral Seminar II	1+0
BIOCHEM 699	Doctoral Research	75

*Core course

Course Contents
Ph.D. in Biochemistry

I. Course Title : Advanced Enzymology

II. Course Code : BIOCHEM 601*

III. Credit Hours : 2+1

IV. Why this course?

The course will make the students able to make a conceptual analysis of the enzymatic reaction mechanism and know the principles of the application of enzymes in analytical biochemistry, and some industrial applications.

V. Aim of the course

To provide advanced knowledge about the structure of enzymes, mechanism, kinetics and regulation of enzymatic reactions and use of enzymes as biosensors.

No.	Blocks	Units
1.	Enzymology and enzyme engineering	1. Enzyme catalysis and specificity 2. Enzyme kinetics 3. Enzyme mechanism and regulation 4. Industrial enzymology

VI. Theory

Block 1: Enzymology And Enzyme Engineering

Unit 1: Enzyme catalysis and specificity (Seven Lectures)

Theory of enzymatic catalysis, Specificity and editing mechanisms, concept of active site and enzyme substrate complex, active site mapping, factors associated with catalytic efficiency, mechanism of enzyme reactions,detection of intermediates in enzymatic reactions.

Unit 2: Enzyme kinetics (7 Lectures)

Transition state theory, Arrhenius equation, Determination of energy of activation, effect of pH and temperature on enzyme kinetics, pre-steady state and steady state kinetics, single substrate kinetics, allosteric enzymes and mixed inhibition, substrate and product inhibition, numerical exercises.

Unit 3: Enzyme mechanism and regulation (7 Lectures)

Mechanism determination by radioisotope exchange, role of enzymes in regulation of metabolism, bifunctional enzymes, pseudoenzyme and enzyme promiscuity, extremozymes, catalytic nucleic acids (ribozymes, catalytic DNA).

Unit 4: Industrial enzymology (7 Lectures)

Advantages and disadvantages of biocatalysis in technology driven processes, stabilization and regeneration of enzyme systems used in biotechnology, protein engineering of enzymes, creation of chimeric, bifunctional, immobilization of enzymes, semisynthetic enzymes and their use as industrial biocatalysts, and their practical significance, modern information technologies in enzyme engineering.

VII. Practicals

- Purification and characterization of some model enzymes (peroxidise, á-amylase, lipase)
- Study kinetics of inhibited and un inhibited enzyme catalysed reactions
- Determination of Km values of single substrate reactions
- Determination of enzyme activity by coupled assay
- Electrophoretic separation of isozymes
- Enzyme immobilization.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

After completing the course students will understand the mode of action of enzymes, mechanisms of enzymatic catalysis and also possible applications of enzymes in various technological processes.

X. Suggested Reading

- Aehle, W. 2007. *Enzymes in Industry. Production and Application.* (Third, Completely Revised Edition*).* Wiley-VCH Verlag GmbH & Co. KGaA
- Buchholz, K., Bornscheuer, U., Kasche, V. 2012. *Biocatalysts and Enzyme Technology*. UK: Wiley-VCH Verlag GmbH
- Fessner, W. and Anthonsen, T. 2009. *Modern Biocatalysis*. Germany: Wiley-VCH Verlag GmbH
- Frey, P.A. and Hegeman, A.D. 2007. *Enzymatic Reaction Mechanisms*. Oxford University Press
- Young Je Yoo, Yan Feng, Yong-Hwan Kim, Camila Flor J. Yagonia. 2017. *Fundamentals of Enzyme Engineering*. Springer

I. Course Title : Advanced Molecular Biology

II. Course Code : BIOCHEM 602

III. Credit Hours : 3+0

IV. Why this course?

To impart knowledge on genome organization and analysis, gene expression and its regulation and modern techniques for genome.

V. Aim of the course

To provide latest information on structure and organisation of genetic materials; genes, their expression in plants and biochemical approaches employed in genetic engineering.

No.	Blocks	Units
1.	Genome organisation and manipulation	1. Concepts of gene and genome 2. Regulation of gene expression 3. Techniques in genome analysis 4. Techniques for gene transfer and genome manipulation 5. Aspects of molecular breeding

VI. Theory

Block 1: Genome Organisation and Manipulation

Unit 1: Concepts of gene and genome (5 Lectures)

Genes, their relationship with chromosomes, gene number hypothesis; Genome – definition, variation and organization in plants and animals, structure of organelle genomes; concept of epigenome, genome size and genome evolution.

Unit 2: Regulation of gene expression (6 Lectures)

Prokaryotic and eukaryotic gene regulation, transcriptional and posttranscriptional regulation; regulation at genome level, role of histones, riboswitches.

Unit 3: Techniques in genome analysis (6 Lectures)

Genome sequencing technologies, Sanger sequencing, next generation sequencing, nanopore sequencing; genome mapping – genetic map construction, physical mapping.

Unit 4: Techniques for gene transfer and genome manipulation (6 Lectures)

Methods of gene isolation and transfer in plants and animals, agrobacterium mediated and direct transfer of genes in plants and animals; gene silencing technologies: virus induced gene silencing, RNA interface; genome editing -TALENs, CRISPR/cas, ZFN and their application, site directed mutagenesis,Application of genetic engineering in different fields, gene therapy.

Unit 5: Aspects of molecular breeding (5 Lectures)

Genome browsing, primer design, marker application for breeding, application of MAS in case studies. Bioethics and bio safety guidelines, IPR in recombinant DNA research

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

On completion of this course, studentswill get an insight into the genome structure, its organization and means for its manipulation for applications in areas such as human and animal health, agriculture, and the environment.

IX. Suggested Reading

- Brown, T. A. 2018. *Genomes 4*. Garland Science

- Rippe, K. 2011. *Genome Organization and Function in the Cell Nucleus*. Wiley VCH Verlag
- Primrose, S. B. and Twyman, R.2006. *Principle of Gene Manipulation and Genomics.* 7th edition. Blackwell Publishing
- Christopher Howe. 2007. *Gene Cloning and Mani*pulation. 2nd edition. Cambridge University Press
- S. Mohan Jain, D S Brar.(eds.). 2009. *Molecular Techniques in Crop Improvement*. 2nd edition. Springer
- Boopathi, N. M. 2013. Genetic Mapping and Marker Assisted Selection: Basics, Practice and Benefits. Springer
- Brown, T. A. 2010. *Gene Cloning and DNA Analysis. An Introduction*. Wiley-Blackwell
- Singh, K. K. 2015. *Biotechnology and Intellectual Property Rights. Legal and Social Implications.* Springer

I. Course Title : Biochemistry of Biotic and Abiotic Stresses

II. Course Code : BIOCHEM 603

III. Credit Hours : 3+0

IV. Why this course?

Plants are constantly confronted to both abiotic and biotic stresses that seriously reduce their productivity. Plant responses to these stresses involve numerous physiological, biochemical, molecular, and cellular adaptations. This course will help to have an insight into the mechanism underlying the stress tolerance and to elucidate the molecular basis of stress adaptation.

V. Aim of the course

To impart knowledge on biochemistry of biotic and abiotic stresses in plants.

No.	Blocks	Units
1.	Biochemistry of biotic and abiotic stresses	1. Plant-pathogen interaction and disease development 2. Biochemistry of plant defence mechanisms 3. Plant host-virus interaction 4. Biochemical basis of abiotic stresses 5. Tolerance against biotic and abiotic stress

VI. Theory

Block 1: Biochemistry of Biotic and Abiotic Stresses

Unit 1: Plant-pathogen interaction and disease development (4 Lectures)

Molecular mechanisms of fungal and bacterial infection in plants; changes in metabolism, cell wall composition and vascular transport in diseased plants.

Unit 2: Biochemistry of plant defence mechanisms (7 Lectures)

Role of secondary metabolites, Plant defence response, antimicrobial molecules; genes for resistance, hypersensitive response and cell death; systemic and acquired resistance, pathogen derived resistance.

Unit 3: Plant host-virus interaction (4 Lectures)

Plant viruses, host-virus interactions, disease induction, virus movement, and host range determination; viroids.

Unit 4: Biochemical basis of abiotic stresses (7 Lectures)

Biochemical basis of abiotic stresses namely osmotic (drought, salinity), temperature, heavy metals, air and water pollutants, synthesis and functions of proline and glycine betaine in stress tolerance interaction between biotic and abiotic stresses; stress adaptation.

Unit 5: Tolerance against stress (6 Lectures)

Reactive oxygen species and biotic and abiotic stress, antioxidants, enzymes of defense system. Role of calcium, nitric oxide and salicylic acid in plant development. Molecular strategies for imparting tolerance against biotic and abiotic stress.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

Upon completion of the course, students will get the suite of molecular and cellular processes that are triggered by plant stress responses.

IX. Suggested Reading

- Buchanan, Bob B., Gruisem, W. and Jones, R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley Blackwell.
- Dresselhaus, T. and Hückelhoven, R. (Eds.) 2019. *Biotic and Abiotic Stress Responses in Crop Plants*. MDPI. https://doi.org/10.3390/agronomy8110267
- Rout, G.R. and Das, A.B. 2013. *Molecular Stress Physiology of Plants*. Springer. DOI 10.1007/978-81-322-0807-5
- Shanker, A.K. and Shanker, C. (Eds.) 2016. *Abiotic and Biotic Stress in Plants - Recent Advances and Future Perspectives*.InTech. http://dx.doi.org/10.5772/60477
- Ramakrishna, A. and Gill, S.S. 2018. *Metabolic Adaptations in Plants During Abiotic Stress*. CRC Press
- Khan, M.I.R. and Khan, N.A. (Eds.). 2017. *Reactive Oxygen Species and Antioxidant Systems in Plants: Role and Regulation under Abiotic Stress*. Springer
- Smirnoff, N. (ed.) 2005. *Antioxidants and reactive oxygen species in plants*, Blackwell

I. Course Title : Frontier Topics in Biochemistry

II. Course Code : BIOCHEM 604

III. Credit Hours : 2+0

IV. Why this course?

To update the students to the recent developments in various fields of biochemistry.

Aim of the Course

To acquaint the students with the advanced developments in the field of biochemistry and to inculcate the habit of searching and reading the topics of current importance.

No.	Blocks	Units
1.	Frontier topics in Biochemistry	1. There will be 8 Units related to different areas in Biochemistry

V. Theory

Block 1: Frontier Topics in Biochemistry

Unit 1: Latest development in metabolic nutrition.

Unit 2: Latest development in environmental and industrial biochemistry.

Unit 3: Latest development in molecular biology techniques.

Unit 4: Latest development in metabolic engineering.

Unit 5: Latest development in regulation of gene expression.

Unit 6: Latest development in biotic and abiotic stress response in plants.

Unit 7: Latest development in protein chemistry.

Unit 8: Topics related to recent approaches concerning application of biochemical tools and techniques

VI. Teaching methods/activities

– Oral presentation by students on specified topics based on recent published research paper
– Group discussion

VII. Learning outcome

Students will build up the habit of searching and studying the topics of current importance and the recent developments in the field of biochemistry.

VIII. Suggested Reading

- Selected articles from recent issues of *Thomson Reuters and NAAS rated journals*

I. Course Title : Concepts and Application of Omics in Biological Science

II. Course Code : BIOCHEM 605

III. Credit Hours : 3+0

IV. Why this course?

Omics is a rapidly evolving, multi-disciplinary, and emerging field that encompasses genomics, epigenomics, transcriptomics, proteomics, and metabolomics. This course will be helpful for the students to understand the scope of omics research and methods therein.

V. Aim of the course

To impart knowledge in the upcoming areas of biochemistry and to understand the recent developments in omic technologies.

No.	Blocks	Units
1.	Concepts and aplication of omics in biological science	1. Protein and nucleic acid sequencing 2. Genomics–methods of analysis and application 3. Proteome technology 4. Metabolomics and ionomics

VI. Theory

Block 1: Concepts and Aplication of Omics in Biological Science

Unit 1: Protein and nucleic acid sequencing (7 Lectures)

Various methods of sequencing including automated sequencing and microarrays, whole genome sequence analysis.

Unit 2: Genomics – methods of analysis and application (7 Lectures)

Comparative genomics, functional genomics, nutrigenomics, transcriptomics, gene identification, gene annotation, pairwise and multiple alignments, application of genomics, quantitative PCR, SAGE, MPSS, microarray, role of bioinformatics in functional genomics.

Unit 3: Proteome technology (7 Lectures)

2D-PAGE, MSMS, MALDI-TOF, comparative proteomics and structural proteomics

Unit 4: Metabolomics and ionomics (7 Lectures)

Elucidation of metabolic pathways, Sample preparation for metabolomics. Techniques involved in metabolite identification- LCMS, NMR, FTIR, MS. Metabolomics in biotic and biotic stress in crop plants, SPE, SPME, metabolic pathway engineering and its application, Concept and application of ionome and ionomics.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

The applications of omics allow the complete profiling of genes, proteins and metabolites to understand the intricacy, complexity and dynamics of biological system. This course serves as an applied course for understanding the applications, research methodologies and data analysis of omics approaches enabling students to apply such skills in their respective projects

IX. Suggested Reading

- Lieber D.C. 2002. *Introduction to Proteomics - Tools for the New Biology*. Humana Press.
- Leung, H.E. 2012. *Integrative Proteomics*. InTech
- Lesk, A.M. 2012. Introduction to Genomics, 2nd Edition. Oxford University Press
- Aizat, W.M., Goh, H-H. and Baharum, S.N. (Eds.) 2018. Omics Applications for Systems Biology. Springer International Publishing
- Arivaradarajan, P., Misra, G. (Eds.) 2018. *Omics Approaches, Technologies and Applications*. Springer Singapore
- Fan TWM, Lane AN and Higashi RM. (Eds.) 2012. *The Handbook of Metabolomics*. Humana Press, Totowa, NJ

I. Course Title : Biomembranes

II. Course Code : BIOCHEM 606

III. Credit Hours : 2+0

IV. Why this course?

Biomembranes define the boundaries of cells and their internal organelles and, consequently, are fundamental to the compartmentalisation of vital enzymatic reactions. This course will help the students to acquire an integrated overview of the structure, function and biogenesis of biological membranes and their components and their impacts on different cell activities.

V. Aim of the course

To impart knowledge on the molecular basis of the structure, function and biogenesis of eukaryotic cell membranes.

No.	Blocks	Units
1.	Biomembranes	There will be 4 Units relating to biomembrane structure, organization, movement and signal transduction.

VI. Theory

Block 1: Biomembranes

Unit 1: Concept of biomembranes and their classification based on cellular organelles; physico-chemical properties of different biological and artificial membranes, cell surface receptors and antigen.

Unit 2: Membrane biogenesis and differentiation; membrane components-lipids, their distribution and organization; proteins, intrinsic and extrinsic, their arrangement; carbohydrates in membranes and their function.

Unit 3: Various membrane movements; Membrane transport: Organization of transport at plant membranes, pumps, carriers, ion channels, water transport through aquaporins, transport of macro molecules: exocytosis and endocytosis, energy transduction.

Unit 4: Role of membrane in cellular metabolism, cell recognition and cell-to-cell interaction; signal transduction, recent trends and tools in membrane research.

VII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

VIII. Learning outcome

This course summarizes the structure and functions of membranes and the proteins within them, and describes their role in trafficking and transport, control the passage of selected compounds, thus maintaining the biochemical integrity of cytosol; communication, allowing the exchange of information between the extra- and intracellular environments, and the physical interaction with the extracellular phase.

IX. Suggested Reading

- Watson, H. 2015. *Biological membranes*. Essays Biochem. **59**, 43–70: doi: 10.1042/BSE0590043
- Shinitzky, M. 2008. *Biomembranes: Structural and Functional Aspects*. VCH. DOI: 10.1002/

9783527616114
- Berk, A., Kaiser, C. A., Lodish, H., Amon, A., Ploegh, H., Bretscher, A., Krieger, M. And Martin, K. C. 2016. *Molecular Cell Biology*. Macmillan Learning
- Stillwell, W. 2013. *An Introduction to Biological Membrane: From Bilayers to Rafts*. Elsevier
- Yeagle, P. 2016. *The Membranes of Cell*. 3rd edition. Academic Press

I. Course Title : Application of Techniques in Biochemistry

II. Course Code : BIOCHEM 607*

III. Credit Hours : 1+2

IV. Why this course?

This course will provide the students the theoretical basis of various separation techniques and their application with practical experience in the use of different biochemical and molecular biology techniques.

V. Aim of the course

To train students the application ofcuttingedge laboratory techniques in research in biochemistry and molecular biology.

No.	Blocks	Units
1.	Application of techniques in Biochemistry	1. Isolation, purification and analysis of metabolites 2. Electrophoretic separation 3. Application of centrifugation 4. Enzyme techniques 5. Molecular biology and immunochemical techniques

VI. Theory

Block 1: Application of Techniques in Biochemistry

Unit 1: Isolation, purification and analysis of metabolites (3 Lectures)

Isolation and purification of important metabolites from microbial/plant/animal source, Applications of paper, thin layer and gas liquid chromatography, PAGE, FPLC and HPLC in the separation of biomolecules. Determination of molecular weight of protein using PAGE/ gel filtration method.

Unit 2: Electrophoretic separation (3 Lectures)

Electrophoretic separation of protein, Experiments on DNA: Isolation, agarose gel electrophoresis and restriction analysis of DNA. Techniques in DNA-protein and protein-protein interaction.

Unit 3: Application of centrifugation (2 Lectures)

Isolation of chloroplast and mitochondria by differential centrifugation and their purification by density gradient centrifugation.

Unit 4: Enzyme techniques (3 Lectures)

Isolation, purification and characterization of enzymes, isozymic analysis and enzyme immobilization.

Unit 5: Molecular biology and immunochemical techniques (3 Lectures)

Application of PCR, yeast 2 hybrid system, Antigen-Antibody interaction, ELISA, Chromatin immunoprecipitation, gel based and gel free proteasome tools.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Demonstration and hands on training
- Exposure visit to institutions equipped with modern facilities

VIII. Learning outcome

This course will help the students in acquiring the laboratory skills required for success in experimental biochemistry and molecular biology.

IX. Suggested Reading

- Katoch, R. 2011. *Analytical Techniques in Biochemistry and Molecular Biology*. Springer
- Wilson, K. and Walker, J. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*, 7th Edition. Cambridge University Press
- Hegyi, G., Kardos, J., Kovács, M., Málnási-Csizmadia, A., Nyitray, L. Pál, G., Radnai, L., Reményi, A. and Venekei, I. 2013. *Introduction to Practical Biochemistry*. EötvösLoránd University

Journals

- *Annual Review of Biochemistry*
- *Annual Review of Genetics*
- *Annual Review of Plant Physiology and Plant Molecular Biology*
- *Biochemical and Biophysical Research Communication*
- *Biochemical Journal*
- *Biochimica Biophysica. Acta*
- *Cell*
- *Current Science*
- *Federation of European Biochemical Society*
- *Food Chemistry*
- *Indian Journal of Experimental Biology*
- *Journal of Agriculture and Food Chemistry*
- *Journal of Biological Chemistry*
- *Journal of Immunology*
- *Journal of Molecular Modelling*
- *Journal of Plant Biochemistry and Biotechnology*
- *Nature*
- *Physiologia Plantarum*
- *Plant Physiology*
- *Plant Science*
- *Planta*
- *Proceedings of National Academy of Sciences, USA*
- *Protein Science*
- *RNA*
- *Science*
- *Scientific American*
- *Trends in Biochemical Sciences*
- *Trends in Biotechnology*
- *Trends in Plant Sciences*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Microbiology

Preamble
(Microbiology)

World is experiencing a rapid shift of national priorities in research and development. Biological science is emerging as one of the top priorities in the field of science, and among the biological sciences microbiology has gained new stature. Microoganisms and their activities are increasingly central to many of the concerns of the society both nationally and internationally. The problem of global environment, the recognition of the need to recycle natural resources, the discovery of genetic engineering – these and other development have placed microbiology in limelight. It is required to restructure and modify the curriculum and the syllabus to enable graduate students to be reacquainted with the developments through providing comprehensive exposure to the M.Sc and Ph.D. students, on new developments in different areas of microbial science.With this background the structure of curriculum for M.Sc. and Ph.D. programmes and syllabi for the courses needs to be developed keeping in view the mandate of agriculture universities and ICAR institutes.

Microbes are indispensable to our life. Interactions of microbes involved in soil, environment, food, fermentation, medical, or agriculture has been studied using modern techniques. New antibiotics, vaccines are also being produced. Moreover, genome sequence of important genes of interest or complete sequence of microbes, plants, human beings or animals has further paved the ways for detailed study of interactions and their manipulations in the desired direction. Molecular analysis of relevant factors in the plant and microbes and components that modulate plant-microbe interactions for soil and plant health for sustaining crop productivity is now being revealed using different molecular techniques. Microbial diagnostic micro arrays have been developed for the parallel, high-throughput identification of many microorganisms.

There is growing recognition in the potential of microorganisms in many applied areas. The ability of microorganisms to decompose materials such as herbicides, pesticides and oil in oils pills; the potential of microorganisms as food supplements; the exploitation of microbial activity to produce energy such as methane gas for natural consumption; and the potential of new therapeutic substances produced by microorganisms – these and other uses of microorganisms are becoming increasingly attractive. Increased attention has been directed towards use of microorganisms (bioremediation) for wastewater treatment involving decolorization of different industrial effluents, which include distillery waste, textile industries and paper and pulp industries. Microbial degradation and decolorization holds promise and can be exploited. But genetic improvement of strains can be explored in future for improving their decolorization efficiency. Some of the agro wastes are being used for the production of biofuels. Use of recombinant microorganisms for industrial production of useful compounds has reached at commercial levels. All these aspects are covered in the coursecurricula.

For MSc programme, 14 courses including master's seminar and master's research are finalized, out of which minor changes have been done in existing 9 courses and one course MICRO 506, Microbial biotechnology, is completely reframed and modified. The aim is to teach students about industrially useful microorganisms and use of fermenter for the production of various primary and secondary metabolites, this course is job oriented. The students can be absorbed by various agro-industries. One new course MICRO501 entitled

Techniques in microbiology has been newly introduced in the syllabus. This course aims to introduce various techniques and instrumentation methods required for the study of microorganisms. This course provides understating on techniques and methods of microscopy, spectroscopy, chromatography and electrophoresis. Courses MICRO 503 and MICRO 504 entitled Microbial physiology and Microbial genetics, respectively, include recombinant DNA technology, commonly related to as genetic engineering, as one of the principal thrust of the emerging technologies in the biological and agricultural sciences. Recombinant DNA technology makes it feasible to consider genetically manipulated (engineered) microorganisms for commercial production of new and valuable products for variety of purposes, e.g., medicinal, fuel and food.

Course No MICRO 505, Soil Microbiology and MICRO 604 Recent approaches in environmental microbiology are introduced with certain important changes with great emphasis on integrated use of chemical fertilizers, pesticides, herbicides along with biofertilizers, biopesticides and biocontrol agents for sustaining modern agriculture and soil health. Biocontrol agents for control of plant diseases, insects, nematodes have been developed and some of these are commercially available and being used by the farmers. Microbe-plant symbiosis within plant rhizosphere have come up as an effective clean up technology.From the earlier syllabus one course entitled Plant microbe interactions has been upgraded from master's programme to Ph.D. level (MICRO 605).

In Ph.D. programme, 8 courses are finalized (including doctoral seminar and research) out of which 3 are the thorough modifications of existing courses.

MICRO 602 Microbial physiology and regulation has been formulated keeping in view following important concepts:

- Basic metabolic pathways can lead to different metabolic groups such as heterotrophs/phototrophs, etc.
- Measurement of growth as influenced by various factors such as media and environmental factor can help to design specific culture media.
- The role of environmental factors in key regulatory points in microorganisms is important in their adoption to the environment
- Enzyme regulation occurs for the cell to adopt in different conditions.
- Role of enzymes in the microorganisms for degradation of substrates for their growth through metabolic pathways may be inductive or conservative determines their expression.

Course No. MICRO 604 Recent Approaches in environmental microbiology has been introduced with the concept:

- How microbes contribute to successful colonization in environment and their interaction with the environment
- Microbiological prospective of public health.
- Certain process like adsorption, immobilization, mobilization and transformation of metal are main processes that can be mediated by action of several microorganisms.
- Microbial bioremediation, biodegradation through species or strains or consortia which are specific to the degradation of one or more types of contaminants for reclamation of environment or remediate polluted sites.

New course MICRO 605 Plant microbe Interaction has been introduced with the concept that–

- The dynamics of plant community is influenced by the microbial association and activity.

- In the plant ecosystems microbes play a defined role to ascertain that plants benefit through provision of nutrients and growth promoting factors.
- At times pathogenic microbes play havoc on the plants, sometimes threatening their very existence.
- The plant serves as habitat for microbial communities. It is the interplay of the interaction between the plant and the microbiome it hosts, that is critical for the establishment and the maintenance of host-microbial homeostasis and defines the overall health and productivity

With a degree in microbiology, students can get opportunities to work in both government as well as private sector, in various fields like healthcare organizations, forensic science laboratories, environmental organizations, higher education institutions, publicly funded research organizations, pharmaceuticals, food and beverages industries, chemical industries, agriculture department, agro-industries, etc.

Microbiology courses are offered by a large number of students hence need small equipment in multiple numbers. To do quality teaching and research, sophisticated equipment like ultra-low freezers, high speed refrigerated-automated bioseparation systems like GLC or HPLC and UV-Vis spectrophotometers suitable for enzyme studies, PCRs, electrophoresis systems for proteins and DNA are required for Microbiology lab. Consumables will also be needed accordingly. An approximate recurring budget of ₹ 20 lacs per annum apart from one time equipment and maintenance grant of ₹ 2 crore will be required.

Course Title with Credit load
M.Sc. (Ag) in Microbiology

Course Code	Course Tittle	Credit Hours
MICRO 501	Techniques in microbiology	0+2
MICRO 502*	Principles of microbiology	3+1
MICRO 503*	Microbial physiology and metabolism	3+1
MICRO 504	Microbial genetics.	2+1
MICRO 505*	Soil microbiology	2+1
MICRO 506	Microbial biotechnology	2+1
MICRO 507*	Food microbiology	2+1
MICRO 508	Bacteriophages	1+1
MICRO 509	Environmental microbiology	2+1
MICRO 510	Industrial microbiology	2+1
MICRO 511	Biofertilizer technology	2+1
MICRO 512	Cyanobacterial and algal biotechnology	2+0
MICRO 591	Master’s seminar	1+0
MICRO 599	Master’s research	30

*Core Courses

Course Contents
M.Sc. (Ag) in Microbiology

Course Title : Techniques in Microbiology
Course Code : MICRO 501
Credit Hours : 0+2

Why this course?

The science of microbiology is the study of microorganisms and their activities. It is concerned with their form, structure, reproduction, physiology, metabolism and identification. It includes the study of their distribution in nature, their relationship to each other and to their living things, their beneficial and detrimental effects on agriculture and the physical and chemical change they make in their environment. In microbiology laboratories, some special equipment and apparatus are commonly used. Students of microbiology should have a general idea of these equipment regarding their constructive features, operation, precaution for use and also the maintenance of the equipment.

Aim of the course

This course aims to introduce various techniques and instrumentation methods required for the study of microorganisms. This course provides understating on techniques and methods of microscopy, spectroscopy, chromatography and electrophoresis.

The course is organized as follows:

No.	Blocks	Units
1	Techniques in microbiology	1. Practical include estimation of microbiological contents of samples like water, soil, air, etc. 2. Operation and care of microscopes 3. Preparation of smears and their morphological observation using microscope 4. Performance of various staining techniques, study of biochemical activities, Identification of microorganisms, preparation of culture media etc.

Practicals

- Awareness about lab safety measures
- Study of general microbiological equipment, cleaning of glassware and apparatus for laboratory use
- Methods of sterilization used in microbiology laboratory
- Use of simple techniques in laboratory (Colorimetry, Centrifugation, electrophoresis and chromatography)
- Types of culture media

- Isolation techniques and direct microscopic count
- Environmental factors affecting bacterial growth: physical chemical, temperature, pH, osmotic pressure, light (UV) and bacteriostatic agents. Bacteriology of air, water, and soil.
- Characteristics of important types of micro-organisms: major functional groups of bacteria, lactic acid, spore forming and coliforms bacteria, fungi, yeast and mold.
- Assessment of microbial quality of portable water.
- Working in microscope

Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures
- Review of policy documents

Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the scientific foundation of general microbiology and relate the key learning to the job of an microbiologist professional
- Utilise methods and tools for microbial agricultural development for the nation.
- Increase the probability of use of different microbial cultures for the benefits of agriculture production

Suggested Reading

- Roy A.K. 2010. *Laboratory Manual of Microbiology* (Practical Manual Series).
- Goldman E and Green LH. 2015. *Practical Handbook of Microbiology*. 3rd Edition. http/ www. CRC press life science Microbiolgy
- Brock, T.D. 2008. *Biology of microorganisms* (Ed.) Madigan MT, Martinko J M, Dunlap P V, Clark D.P., 12th ed. Pearson, New Jersey.
- Pelczar, M.J. Jr., Chan, E.C.S. and Kreig, N.R. 1997. *Microbiology, Concepts and Application*, 5th edition, Tata McGraw Hill, New York.
- Prescott, L.M., Harley and Klein. 2002. *Microbiology* 5th Edition, Tata McGraw Hill, New York.
- Bhatia, M.S. 2009. *Principles of Microbiology*. Swastik Publishers., DeIhi.
- Madigan, M.T., J.M. Martinko, P.V. Dunlap and D.P. Clark. 2001. *Brock biology of Microorganism* 10th Ed. Pearson Education lnc, USA.
- Singh, U.S. and K. Kapoor 2010. *Introductory microbiology* Oxford Book Company., Jaipur
- Tortora, G.J., B.J. Funke and C.L. Case. 2010. *Microbiology: an introduction*.10th Ed. Benjamin Cummings., New York.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

Course Title : **Principles of Microbiology**
Course Code : **MICRO 502***
Credit Hours : **3+1**

Why this course?

Microbes has become a part and parcel of our lives This course is required for the future battle against infectious diseases worldwide, understanding the environmental importance of microbes and to exploit them for food production, biotechnological and industrial applications. Hence, this customized course.

Aim of the course

The main focus of our course is the potential of the organisms that cause disease and benefits in the society. You will also cover aspects of the biochemistry, physiology and genetics of microorganisms.

The course is organized as follows:

No.	Blocks	Units
1.	Scope and History of Microbiology and microscopy	1. Scope of microbiology 1. History routes 2. Staining and microscopy
2.	Evolutionary link of prokaryotes	1. Phylogenetic classification 2. Methods of sequencing
3.	Microbial growth, characterization and regulation	1. Microbial growth and reproduction 2. Sterilization techniques 3. Nutritional requirements for microbial growth

Theory

Block 1: Scope and History of Microbiology and Microscopy

Unit 1: Scope of microbiology

Scope of microbiology, microbes and microbiologist. Emergence of Special Fields of Microbiology.

Unit 2: History Routes

The Germ Theory of Disease, Early Studies: Pasteur's Further Contributions, Koch's Contributions, Work Toward Controlling Infections, spontaneous generation theory.

Unit 3: Staining and microscopy

Microscopy; Bright field, Dark field, Phase contrast, Confocal, Fluorescence, TEM, SEM – Working Principles and applications; Properties of light; Simple staining, differential and special staining.

Block 2: Evolutionary Link of Prokaryotes

Unit1: Phylogenetic classification

Evolutionary relationship among prokaryotes. Prokaryotes and Eukaryotes, Phylogenetic and numerical taxonomy. Species concept.

Unit2: Methods of sequencing

Use of DNA and r-RNA sequencing in classifications.

Block 3: Microbial Growth, Characterization And Regulation

Unit1: Microbial growth and reproduction

Microbial growth and reproduction-communication, bacteria, yeast and virus growth, Replication, Cultivation methods, Normal micro flora of Human body; Immune response- specific and non-specific host resistance.

Unit 2: Sterilization techniques

Physical and chemical methods of sterilisation.

Unit 3: Nutritional requirements for microbial growth

Classification of microbes: electron, energy and carbon sources.

Practicals

- Working principles and handling of different types of microscopes – Bright and Dark field microscopy
- Working principles and handling of different types of microscope- SEM and TEM
- Methods of isolation from different environments – soil, water, milk and food
- Use of selective media for isolation
- Purification techniques of bacteria and fungi
- Enumeration and Quantification techniques
- Maintenance and preservation of cultures
- Assessment of microbial quality of portable water.
- Morphological characterization of Bacteria
- Morphological characterization of fungi
- Biochemical characterization of bacteria
- Biochemical characterization of fungus

Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures
- Review of policy documents

Learning outcome

After successful completion of this course, the students are expected to be able to:

- Knowledge on historical perspective of Microbiology
- Basic knowledge on different structure of microbes

Suggested Reading

- Brock TD. 2008. *Biology of microorganisms* (Ed.) Madigan MT, Martinko J M, Dunlap P V, Clark DP, 12th ed. Pearson, New Jersey.
- Pelczar MJ. Jr., Chan, ECS and Kreig NR. 1997. *Microbiology, Concepts and Application*, 5th edition, Tata McGraw Hill, New York.
- Prescott, L.M., Harley and Klein. 2002. *Microbiology* 5th Edition, Tata McGraw Hill, New York.
- Bhatia, M.S.2009. *Principles of Microbiology*. Swastik Publishers., DeIhi.
- Madigan, M. T., J. M. Martinko, P.V. Dunlap and D.P. Clark.2001. *Brock biology of Microorganism* 10th Ed. Pearson Education lnc, USA.

- Singh, U.S and K. Kapoor 2010. *Introductory microbiology* Oxford Book Company., Jaipur
- Tortora, G. J., B.J. Funke and C.L. Case. 2010. *Microbiology: an introduction*.10th Ed. Benjamin Cummings., New York
- Davis BD, Dulbecco R, Eisen HN and Ginsberg HS. 1990. *Microbiology* (4th edition). J.B.Lippincott company, Newyork.
- Alexopoulus CJ and C W. Mims. 1993. *Introductory Mycology* (3rd edition).Wiley Eastern Ltd, NewDelhi.
- Elizabeth Moore-Landecker. 1996. *Fundamentals of the fungi*. (4th edition).Prentice Hall International, Inc, London.
- Heritage,J. Evans E.G.V. and Killington, R.A. 1996. *Introductory Microbiology*. Cambridge University Press.
- Webster J. 1993. Introduction to Fungi.(2nd edition).Cambridge University press,Cambridge.
- Prescott LM, Harley JP and Klein DA. 2006. Microbiology (7th edition) McGraw Hill, Newyork.
- Schaechter M and Leaderberg J. 2004. The Desk encyclopedia of Microbiology. Elseiver Academic press, California.
- Nester, E.W., Roberts, C.V. and Nester, M.T. 1995. *Microbiology: A human perspective*. IWOA, U.S.A.
- Pelczar Jr, M.J. Chan, E.C.S. and Kreig, N.R. 1993. *Microbiology*, Mc. Graw Hill. Inc, New York.
- Holt JG and Bergey DH. 1994. *Bergey's Manual of Determinative Bacteriology* (9th Edition), Williams and Wilkins, Baltimore.
- Mara D. and Horan N. 2003. *The Handbook of Water and waste water Microbiology*. Academic Press-An imprint of Elsevier.
- Madigan M T, Bender K S, Buckley HD, Sattley WM, Stahl DA 2017. *Brock Biology of Microorganisms* - 15^{th} edition. Pearson Education, USA.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

I. Course Title : Microbial Physiology and Metabolism

II. Course Code : MICRO 503*

III. Credit Hours : 3+1

IV. Why this course?

Microbial physiology is defined as the study of how microbial cell structures, growth and metabolism function in living organisms. Microbial physiology is important in the field of metabolic engineering and also functional genomic. The study of diversity of microbial metabolic processes & their regulation, how microbes respond to environment stress and manipulation and the genetic control of these processes are essential for their potential applications of microbial process for the production of commercial products.

V. Aim of the course

Microorganisms have tremendous metabolic diversity hence it's intriguing to learn how these small creatures deal with different environmental conditions and either adopt themselves to it or convert it to favourable conditions by involving different physiological processes. The contents of this course will help students how microbes can grow on substrates other than glucose, their inorganic metabolism and photosynthesis and how do they respond to the changes in environment. It will elaborate the anaerobic respiration by variety of groups of microbes and non-genetic regulation at metabolic pathways.

The course is organized as follows:

No.	Blocks	Units
1.	Scope of microbial growth and physiology	1. Structure, function and biosynthesis of cellular components
2.	Pathways and their significance; Growthkinetics and nutritional classifications	1. Growth Kinetics, cell cycle, cell division, pathways and fermentation metabolism. 2. Growth and factors affecting growth and culture systems. 3. Nutritional classification and spore formation and germination
3.	Enzymes and microbial metabolisms	1. Kinetics and Mechanism of Enzymes 2. Microbial metabolism
4	Synthesis of macromolecules	1. Biosynthesis of macromolecules

VI. Theory

Block 1: Scope of Microbial Growth and Physiology

Unit 1: Structure, function and biosynthesis of cellular components

Microbial nutrition – Chemical composition of microbial cell – Structure, function and assembly of cell membrane in prokaryotes, archaea and fungi – Macro and Micro- nutrients and their physiological functions – Transport of solutes across the membrane

Block 2: Pathways and their Significance; Growth Kinetics and Nutritional Classifications

Unit 1: Growth Kinetics, cell cycle, cell division, pathways and fermentation metabolism

Microbial growth. Cell cycle and cell division. Bioenergetics -carbohydrate utilization via EMP, HMP, ED, TCA pathways, Aerobic and anaerobic respiration. Fermentative metabolism. Assimilation of nitrogen and sulphur - Oxygenic and anoxygenic photosynthesis - Mechanisms of carbon-dioxide fixation in prokaryotes. Ethanol, lactic acid, butanol, acetone and mixed acid fermentation. Fermentation of nitrogenous organic compounds Regulation of microbial metabolism.

Unit 2: Growth and factors affecting growth and culture systems

Effects of physical, chemical and other environmental factors on growth Continuous culture, Diauxic growth and Synchronous culture. Method of growth measurement. Morphogenesis and cellular differentiation.

Unit 3: Nutritional classification and spore formation and germination

Metabolic diversity in photoautotrophs, photoheterotrophs, chemoautotrophs and chemoheterotrophs. Nutritional grouping/classification of microorganisms. Bacterial endospore-types, morphology, biochemistry and regulation of formation and germination

Block 3: Enzymes and Microbial Metabolisms

Unit 1: Kinetics and Mechanism of Enzymes

Enzyme kinetics: Michaelis Menten kinetics - mechanisms of inhibition of enzyme activity - coenzymes and prosthetic groups.

Unit 2: Microbial metabolism

Methods to determine free energy of biochemical reactions - high energy compounds. Microbial metabolism: generation of ATP, reducing power, development of proton gradient and biosynthesis of ATP.

Block 4: Synthesis of Macromolecules

Unit 1: Biosynthesis of macromolecules

Biosynthesis of macromolecules – Synthesis and assembly of cell wall components – Methods of studying biosynthesis - regulation of microbial metabolism.

VII. Practicals

- Use of simple techniques in laboratory (Colorimetry, Centrifugation, electrophoresis and GLC, etc.).
- Determination of viable and total number of cells.
- Measurement of cell size.
- Gross cellular composition of microbial cell. Growth – Factors affecting growth.
- Study of bacterial spores and factors affecting germination.
- Enzyme activity and kinetics – calculating Km and V_{max} of enzyme.
- Demonstration of thermos-, meso-, and psychrophilic micro-organisms.
- Production and testing of inducible enzymes in bacteria.
- Sporulation and spore germination in bacteria.
- Protoplasts formation and regeneration.
- Estimation of generation time and specific growth rate for bacteria and yeast.
- Diauxic growth curve.
- Production of synchronous cells.
- Effect of chemicals and environmental factors on bacterial growth.
- Isolation and Identification of reserve food material (Glycogen/ polyphosphates, PHB) from bacteria (*Azotobacter*, *Bacillus megaterium*).
- Growth of microorganisms on various carbon and nitrogen sources.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Knowledge about cell cycle and microbial pattern
- Growth and practical training on methods to determine microbialgrowth

X. Suggested Reading

- Moat, A. G. and J. W. Foster. 2002. *Microbial Physiology*. John Wiley & Sons, New York,

USA. 11th ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- Madigan, M.T, J.M. Martinko and J. Parker. 2006. *Brock: Biology of Microorganisms*, 11th ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- White, D. 2007. *The Physiology and Biochemistry of Prokaryotes*, 3rd Edition. Oxford University Press.
- Downs, D. M. 2006. *Understanding microbial metabolism*. Annual Review of Microbiology 60, 533–559.
- Hosler *et al.* 2006. *Energy Transduction: Proton Transfer Through the Respiratory Complexes*. Annual Review of Biochemistry 75, 165-187.
- Okuno *et al.* 2008. *Correlation between the conformational states of F1-ATPase as determined from its crystal structure and single-molecule rotation*. PNAS 105(52): 20722-20727.
- Itoh et al (2004) Mechanically driven ATP synthesis by F1-ATPase. Nature 427, 465-468.
- Doelle HW. 1969. *Bacterial Metabolism*. Academic Press.
- Gottschalk G. 1979. *Bacterial Metabolism*. Springer Verlag.
- Nelson DL and Cox MM. 2017. *Lehninger*, *Principles of Biochemistry,* 4th Edition, W.H.Freeman & Company, 2004. (T1)
- Voet D and Voet JG. 2002. *Fundamentals of Biochemistry*, Upgrade Edition, Wiley.

Journals
- *Journal of Bacteriology.*
- *Advances in Microbial Physiology.*
- *Soil Biology and Biochemistry.*
- *Journal of Applied Bacteriology.*
- *Applied and Environmental Microbiology.*
- *Microbiology.*

Websites
- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.textbookofbacteriology.net
- https://www.e-education.psu.edu
- http://www.ncbi.nlm.nih.gov/pubmed/12050002
- http://www.journals.elsevier.com/bba-bioenergetics/
- http://www.bmb.leeds.ac.uk/illingworth/oxphos
- http://www.atpsynthase.info/
- https://ocw.um.edu.my/course/view.php?id=67
- https://mic.microbiologyresearch.org/content/journal/micro/10.1099/mic.0.037143-0

I. Course Title : Microbial Genetics

II. Course Code : MICRO 504

III. Credit Hours : 2+1

IV. Why this course?

Microbial Genetics has traditionally been a field of basic science research as microorganisms offer several features that facilitate the study of evolutionary process,understanding the genotype and its expression system. Students also hone their abilities to read, understand and critically evaluate research articles as well as improve presentation skills.

V. Aim of the course

This course is designed to provide an understanding of the fundamentals of genetic

processes in prokaryotes and eukaryotes. The study of microbial genetics has provided much of the understanding of fundamental genetic processes for all organisms, especially through the use of *in vivo* and *in vitro* genetic tools.
The course is organized as follows:

No.	Blocks	Units
1.	Introduction to microbial genetics	1. Historical perspectives of microbial genetics 2. Genome of prokaryote, eukaryote (fungi) and virus 3. Genetic elements - chemical structure and property, enzymes associated and replication 4. Extra-chromosomal DNA in bacteria and eukaryotic cells
2.	Gene expression and regulation	1. Introduction to Gene structure and expression 2. Regulation of gene expression
3.	Mutation, genetic recombination and sequencing	1. Principles of mutation and types 2. Mutagens and their mode of action 3. DNA damage – DNA repair mechanisms in bacteria 4. Genetic recombination in bacteria 5. Gene Sequencing

VI. Theory

Block 1: Introduction to Microbial Genetics

Unit 1: Historical perspectives of microbial genetics

Introduction to Microbial genetics; Historically important events and major contributions of scientists in the field of Microbial genetics; Terminologies employed in microbial genetics and definitions; Nucleic acid – overview DNA, RNA.

Unit 2: Genome of prokaryote, eukaryote (fungi) and virus

Bacterial genome Eukaryotic genome; Viral genome; Difference between prokaryotic and eukaryotic genome; Mechanisms and role of prokaryotic genome- an overview.

Unit 3: Geneticelements - chemical structure and property, enzymes associated and replication

Structure of DNA – A form, B form, Z form; RNA- tRNA, mRNA, rRNA; Role and Replication of DNA and RNA; Enzymes involved in Replication and its role.

Unit 4: Extra-chromosomal DNA in bacteria and eukaryotic cells

Plasmids, Mitochondrial DNA, Chloroplast DNA – structure and function.

Block 2: Gene Expression and Regulation

Unit 1: Introduction to gene structure and expression

Gene structure and expression, principles of operon, gene expression in prokaryote and eukaryotes, intron and exons, post transcriptional modifications.

Unit 2: Regulation of gene expression

Regulation of gene expression, negative expression (lac operon and trp operon), positive regulation (cAMP).

Block 3: Mutation, Genetic Recombination and Sequencing

Unit 1: Principles of mutation and types

Principles of mutation, spontaneous and induced mutation, different types of mutations, selection principles of mutants.

Unit 2: Mutagens and their mode of action

Mutagens and their mode of action, transposable elements and insertion sequences.

Unit 3: DNA damage - DNA repair mechanisms

DNA damage, DNA repair mechanisms in bacteria.

Unit 4: Genetic recombination in bacteria

Genetic recombination in bacteria, mechanisms of recombination, transformation, conjugation, transduction.

Unit 5: Gene sequencing

Gene cloning and gene sequencing. Impact of gene cloning, polymerase chain reaction, DNA sequencing, recombinant DNA technology.

VII. Practicals

- Isolation of genomic DNA from pure cultures of bacteria and fungi.
- Visualization of mega plasmids of bacteria.
- Isolation of bacterial plasmids and Plasmid curring.
- Qualitative and quantitative assay of DNA by spectrometry and gel-electrophoresis.
- Inducing mutation by chemicals, physical and biological agents.
- Transformation and selection of transformants.
- Amplification of gene of interest by PCR – cloning and expression.
- Isolation of metagenomic DNA from environmental samples.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group work in practical
– Field visit
– Case studies

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Identify and distinguish genetic regulatory mechanisms at different levels
– Plan basic experiments in Microbial genetics
– Describe and summarize experimental work in a correct way.

X. Suggested Reading

- Brown TA. 2001. *Gene Cloning and DNA Analysis: An Introduction*. Fourth Edition. Blackwell Science Inc., Oxford, UK.
- Levin B. 2002. *Gene VIII.* Oxford Univ. Press, New York. p.990.
- Maloy SR, Cronan JE, Freifelder D. 2008. *Microbial Genetics* - second edition. Narosa Publising house, New Delhi. p. 525.
- Omoto CK and Lurquin PF. 2004. *Genes and DNA: a beginner's guide to genetics and its applications*. Colambia University Press, USA.
- Sambrook J, Fritsch EF, Maniatis T. 2000. *Molecular Cloning: A laboratory Manuel*. Third Edition. Cold Spring Harbor Press, New York.

- Streips UN, Yasbin RE. 2006. *Modern Microbial Genetics*. Wiley – Liss. John Wiley & sons, Inc. Publication, NY.
- Birge EA. 1981. *Bacterial and Bacteriophage Genetics*. Springer Verlag.
- Gardner JE, Simmons MJ and Snustad DP. 1991. *Principles of Genetics*. John Wiley& Sons.
- Lewin B.1999. *Gene*. Vols. VI-IX. John Wiley & Sons.
- Maloy SR, Cronan JE and Friedfelder D. 2008. *Microbial Genetics*. Narosa.
- Scaife J, Leach D and Galizzi A 1985. *Genetics of Bacteria*. Academic Press. William Hayes 1981. *Genetics of Bacteria*. Academic Press.
- Strips UN, Yasbin RE *2006. *Modern Microbial Genetics*. Wiley-Liss, NY.

Websites

- http://highered.mcgraw-hill.com/sites/0072552980/student_view0/chapter9/
- http://highered.mcgrawhill.com/sites/0072835125/student_view0/animations.html
- http://cwx.prenhall.com/brock/
- http://www.cliffsnotes.com/sciences/biology/microbiology
- http://plato.acadiau.ca/courses/biol/Microbiology/home.HYPERLINK "http://plato.acadiau.ca/courses/biol/Microbiology/home.html"html
- http://www.learner.org/courses/biology/index.html

I. Course Title : Soil Microbiology

II. Course Code : MICRO 505*

III. Credit Hours : 2+1

IV. Why this Course?

Understanding the function of the soil ecosystem in relation to ever changing soil conditions is key to understanding the basic mechanisms of soil productivity. This is important in light of the urgency to change agricultural practices and also the problems of xenobiotic compounds in soils. The possible perturbations caused by pollution, intense agricultural practices or changing land use–are of major concern.

The possibility of involvement of nonculturable or minute cell fractions requires innovative research using molecular biological techniques. Information on the effects of different root parts versus bulk soil is interesting. Role of microorganisms in biogeochemical cycles and their interactions decide the nutrients available to crops.

The rhizosphere–the micro environment around plant roots houses intense biological, physical and geochemical activity distinguishing it from surrounding soil. Diversity, distributions, activities and interactions of innumerable organisms affect and are affected by availability of energy and nutrients, soil-water content and rhizosphere redox states. Soil food webs and nutrient cycling in agro ecosystems is of prime concern.

V. Aim of the course

- To help unlock and harness the potential of microorganisms in soil.
- To know the potential benefit of consortia of microorganisms to protect plants from different stresses.
- To study the role of microorganisms in the ecosystem functioning, nutrient cycling and biogeochemical processes including soil enzymes, through their metabolic activity and interactions.

The course is organized as follows:

No.	Blocks	Units
1.	Developments in soil Microbiology and Soil parameters	1. Historical prospective of soil microbiology. Factors affecting soil microflora 2. Ecology of soil microbiology
2.	Microbiology and Biochemistry of Plant parts	1. Plant parts and soil interface interaction
3.	Role of microorganisms in nutrient biocycle	1. Microbial transformations of various nutrients 2. Microbial degradation of organic matter 3. Microbial diversity 4. Role of microorganisms in biodegradation of xenobiotics and pesticides.

VI. Theory

Block 1: Developments in Soil Microbiology and Soil Parameters

Unit 1: Historical prospective of soil microbiology. Factors affecting soil microflora.

Landmarks in the history of soil microbiology. Abiotic factors (physical and chemical) affecting soil microflora as pH, chemicals, moisture, air, temperature etc.

Unit 2: Ecology of soil microbiology

Soil biota, Soil microbial ecology, types of organisms in different soils; Soil microbial biomass; Microbial interactions: unculturable soil biota.

Block 2: Microbiology and Biochemistry of Plant Parts

Unit 1: Plant parts and soil interface interaction

Microbiology and biochemistry of root-soil interface; phyllosphere, plant growth promoting rhizobacteria, soil enzyme activities and their importance.

Block 3: Role of Microorganisms in Nutrient Biocycle

Unit 1: Microbial transformation of various nutrients

Microbial transformations of nitrogen, phosphorus, sulphur, iron and manganese in soil. Siderophores and antimicrobials.

Unit 2: Microbial degradation of organic matter

Biochemical composition and biodegradation of soil organic matter and crop residues.

Unit 3: Microbial diversity

Endophytic microorganisms Mycorrhizae, types and role in phosphate mobilization. Potassium releasing bacterium. Microbes in biotic and abiotic stress management.

Unit 4: Role of microorganisms in biodegradation of xenobiotics and pesticides

Biodegradation of pesticides, Organic wastes and their use for production of biogas and manures: Biotic factors in soil development.

VI. Practicals

- Determination of soil microbial population

- Determination of Soil microbial biomass
- Decomposition studies in soil, Soil enzymes
- Measurement of important soil microbial processes such as ammonification, nitrification
- N_2 fixation, S oxidation, P solubilization and mineralization of other micro nutrients
- Study of rhizosphere effect
- Microbial diversity Endophytic microorganisms
- Mycorrhizae, types and role in phosphate mobilization Potassium releasing bacterium
- Microbes in biotic and abiotic stress management

VII. Teaching methods/activities

- Lectures. To use ppt and video clippings whenever necessary based on the topics that are hard to understand.
- The students must be assigned either in individual or in groups to identify the soils and crops grown and must get respective soil samples and plants for analyzing the microorganisms. They must subject the culture for various analysis depending upon the culture such a nitrogen fixing ability, phosphate solubilising property etc.
- Testing their efficiency through growth studies

VIII. Learning outcome

- Students will become familiar to the types of microbes in soil and their association with plants.
- The exclusive role of microorganisms in plant growth can be thoroughly understood.

IX. Suggested Reading

- Paul EA. 2015. *Soil Microbiology, Ecology and Biochemistry*. Elsevier
- Jan Dirk Van Elsas, Trevors JT and Elizabeth M.H. Wellington, 1997. *Modern Soil Microbiology*. Marcel Dekker, Inc.
- Paul EA. 2007. *Soil Microbiology and Biochemistry* 3rd Edition. Academic Press.
- Cardon ZG and Whitbeck JL. 2007. *The Rhizosphere An Ecological Perspective*. Academic Press.
- Schulz BJE, Boyle CJC and Sieber TN (Edrs). 2006. *Microbial Root Endophytes*. Pub Springer.
- Magesin R and Schinner F. (Edrs). 2005. *Manual of soil analysis monitoring and assessing soil Bioremediation*. Pub: Springer.
- Pinton R, Varanini Z and Nannipiers P. The Rhizosphere Biochemistry & organic substances at the soil-plant interface. Pub: CRC Press.
- Prasad TV. 2011. *A Text Book of Soil Microbiology*. Dominant Publishers & Distributors, New Delhi.
- Mukerji KG, Manoharachary C and Singh J. 2006. *Microbial activity n the Rhizosphere*. Pub: Springer.

Journals

- *European Journal of Soil biology*.
- *Canadian Journal of Microbiology*
- *Annual Review of Microbiology*
- *Journal of the Indian Society of Soil Science.*
- *Soil Biology and Biochemistry*
- *Applied soil ecology*

Websites

- www.nature.com
- www.microbiologysociety.org
- www.sare.org

I. Course Title : Microbial Biotechnology

II. Course Code : MICRO 506

III. Credit Hours : 2+1

IV. Why this course?

To give practical knowledge on fermentation and to develop fermentation for industrial application. Hence, this customised course.

V. Aim of the course

The aim is to teach students about industrially useful microorganisms and use of fermentor for the production of various primary and secondary metabolites
The course is organized as follows:

No.	Blocks	Units
1.	Scope of Microbial Technology and Fermentation Metabolism	1. Microbial Biotechnology 2. Fermentation Metabolism 3. Fermenter/bioreactor design and 4. operation 5. Fermentation system
2.	Recombinant products	1. Production of recombinant
3.	Microbial conversion and their product formation	1. Industrial production of beverages, acids and solvent 2. New tools and recent advances in microbial biotechnology

VI. Theory

Block 1: Scope of Microbial Technology and Fermentation Metabolism

Unit1: Microbial Biotechnology:

Introduction, Scopes, historical development, application and challenges.

Unit 2: Fermentation Metabolism

Fermentative metabolism, isolation, preservation screening and genetic improvement of industrially important microbes; Microbial growth kinetics.

Unit 3: Fermenter/bioreactor design and operation

Fermenters – types of fermenter, stirred tank reactor, bubble column reactor, airlift reactor, packed bed reactor, fluidized bed reactor and trickle bed reactor, agitation and aeration in a reactor, mass transfer. Foam formation and control.

Unit 4: Fermentation system

Types, Batch, Fed batch and continuous fermentation- multistage system. Solid state fermentation, Overproduction of primary and secondary metabolites e.g. amino acids, organic acids, alcohols, enzymes, organic solvents, antibiotics, etc. Immobilization of enzymes; and cells; Scale-up principles; Down-stream processing, etc.

Block 2: Recombinant Products

Unit 1: Production of recombinant

Current advances in production of antibiotics, vaccines, and biocides; Steroid transformation; Bioprocess engineering; Production of recombinant DNA products, Immobilization techniques.

Block 3: Microbial Conversion and their Product Formation

Unit 1: Industrial production of beverages, acid and solvent

Production of alcohol (ethanol, wine and beer) and improvement by genetic engineering. Microbial production of acids (citric, acetic and gluconic acid) solvents (glycerol acetone and butanol) aminoacids (lysine and glutamic acid).

Unit 2: New tools and recent advances in microbial biotechnology

Concept of probiotics and applications of new tools of biotechnology for quality feed/food production; Microorganisms and proteins used in probiotics; Lactic acid bacteria as live vaccines; Bioconversion of substrates, anti-nutritional factors present in feeds; Microbial detoxification of aflatoxins; Microbial polysaccharides: fermentative production of xanthan gums. Bacterial bioplastics, genetic engineering of microorganisms for the production of poly-3 hydroxyalkanoates. Single cell protein, Bio-insecticides; Bio-fertilizers; Waste as source of energy/food Microbiologically-produced food, colours, and flavours. Retting offlax. Recent advances in microbial biotechnology.

VII. Practicals

- Isolation and maintenance of industrially important microbes
- Production of alcohol
- Production of beer
- Production of citric acid
- Production of lactic acid
- Standardization of physical factors for the higher production of citric acid
- Production and assay of antibiotics
- Production of pullulan
- SCP production
- Study of bioreactors and their operation

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Better knowledge on industrially important microbes
- Important downstreaming processes followed for product development

X. Suggested Reading

- Cruger W and Cruger A. 2004. *Biotechnology - A Textbook of Industrial Microbiology*. 2nd Ed. Panima.
- Ward OP. 1989. *Fermentation Biotechnology*. Prentice Hall.
- Wiseman A. 1983. *Principles of Biotechnology*. Chapman & Hall

- Peppler HJ and Perlman D.1979. *Microbial Technology*. 2nd Ed. Academic Press.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

I. Course Title : Food Microbiology

II. Course Code : MICRO 507*

III. Credit Hours : 2+1

IV. Why this course?

Food Microbiology focuses on a wide variety of current research on microbes that have both beneficial and deleterious effects on the safety and quality of foods, and are thus a concern of public health.

This course, food microbiology focuses specifically on issues of food spoilage caused by the presence of food-borne pathogens. Students are instructed in methods of sanitation and preservation during food preparation and processing.

V. Aim of the course

To familiarize the students with recent advances in food microbiology including fermented foods, dairy, food preservation, detection of food- borne diseases, their control measures.

The course is organized as follows:

No.	Blocks	Units
1	Historical Perspective and Scope of Microbiology in relation to food	1. Importance and significance of microorganisms in food 2. Factors of special significance in Food Microbiology 3. Microbial spoilage of different types of foods
2	Fermentation and Food Preservation methods	1. Food fermentation 2. Preservatives and preservation methods
3	Food safety and Quality Management Systems	1. Advanced techniques in detecting food-borne pathogens and toxins.

VI. Theory

Block 1: Historical Perspective and Scope of Microbiology in Relation to Food

Unit 1: Importance and significance of microorganisms in food

Introduction and scope; Food Microbiology Important microorganisms in food and their sources. Importance and significance of microorganisms in food.

Unit 2: Factors of special significance in Food Microbiology

Intrinsic and extrinsic factors influencing microbial growth in foods; Spores and their significance; Indicator organisms and Microbiological criteria.

Unit 3: Microbial spoilage of different types of foods

Microbial spoilage of meat, milk, fruits, vegetables and their products. Food-borne pathogens (bacteria, fungi and viruses) and intoxication.

Block 2: Fermentation and Food Preservation Methods

Unit 1: Food fermentation

Fermented dairy, vegetable, meat products.

Unit 2: Preservatives and preservation methods

Physical methods, chemical preservatives and natural antimicrobial compounds. Biologically based preservation systems. Foods for Specified Health Probiotic bacteria; Bifidus factor. Bacteriocins and their applications; Pre-, probiotics and symbiotics. Microbes as food single cell protein.

Block 3: Food Safety and Quality Management Systems

Unit 1: Advanced techniques in detecting food-borne pathogens and toxins

Food safety and Quality Management Systems- General principles of food safety risk management, Recent concerns on food safety- Safe food alternatives (Organic foods), Good agricultural Practices (GAP), Food Indicators of water and food safety and quality Advanced techniques in detecting food-borne pathogens and toxins. HACCP (Hurdle technology and Hazard analysis. Critical control point) CODEX, FSSAI (Food Safety and Standard Authority of India) systems in controlling microbiological hazards infoods. Food safety regulations

VII. Practicals

- Statutory, recommended and supplementary tests for microbiological analysis of various foods
- Infant foods, canned foods, milk and dairy products, eggs, meat, vegetables, fruits, cereals, surfaces, containers, normal, spoiled, processed, fermented food and water
- Testing of antimicrobial agents
- Analysis of water
- HACCP Plan
- Visit to Food processing Industries

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work in Practical
– Visit to Food processing Industries

IX. Learning outcome

With this course the students are expected to be able to learn

– Important microorganisms in food and their sources.
– Various Factors of special significance in Food Microbiology.
– Biologically based preservation systems of foods.
– Advanced techniques in detecting food-borne pathogens and toxins.

X. Suggested Reading

- Bibek Ray. 1996. *Fundamentals of Food Microbiology*. CRC Press.
- Frazier W.C. and Westhoff D.C. 1991. *Food Microbiology*. 3rd Ed. Tata McGraw Hill.
- George J Banwart. 1989. Basic Food Microbiology. AVI. James M Jay. 1987. Modern Food Microbiology. CBS.

- Peppler H.J. and Perlman D. 1979. *Microbial Technology*. 2nd Ed. Academic Press.
- Adams, M.R., and M. O. Moss 1996. *Food Microbiology*, New Age International (Rt) Ltd., New Delhi.
- Frazier, W.C. and D.C. Westhoff, 1988. *Food Microbiology* (Reprint 1995), Tata McGraw Hill Publishing Ltd., New Delhi.
- James M. Jay., Loessner, M.J. and Golden D.A. 2005. *Modern Food Microbiology*, Seventh edition.
- Verma, L.K. and Joshi, V.K. 2000. *Post Harvest Technology of Fruits and Vegetables*, Tata McGraw Hill Publication.
- Bhunia AK. 2008. *Foodborne Microbial Pathogens- Mechanisms and Pathogenesis, Food Science text Series*, Springer International, New York, USA.
- Benwart, G.J. 1987. *Basic Food Microbiology*, CBS Publishers & Distributors, New Delhi.
- Deak, T. and Beuchat LR. 1996. *Hand Book of Food Spoilage Yeasts*, CRC Press, New York.
- Doyle, M.P. and Beuchat, L. R. 2007. *Food Microbiology- Fundamentals and Frontiers*, ASM Press.
- Garbutt, J., 1997. *Essentials of Food Microbiology*, Armold – International Students edition, London.
- Marriott, N.G. and Gravani R. B. 2006. *Principles of Food Sanitation, Food Science text Series*, Springer International, New York, USA.

Websites

- https://www.journals.elsevier.com/food-microbiology
- https://www.nature.com/subjects/food-microbiology
- https://www.frontiersin.org/journals/microbiology/sections/food-microbiology
- https://www.sciencedirect.com/journal/food-microbiology

I. Course Title : Bacteriophages

II. Course Code : MICRO 508

III. Credit Hours : 1+1

IV. Why this Course?

Bacteriophages are viruses that infect and reproduce in bacteria. Phages are inherently highly specific towards bacterial hosts. This characteristic has both negative and positive aspects in that it is beneficial in terms of avoiding negative effects on the host microbiota and a hindrance when it comes to detection and elimination of the target pathogen Course is formulated to demonstrate the complete sequence of host parasite reactions and provide a model by which virus –host cell reactions can be postulated for infection in higher plants and animals.

V. Aim of the course

To familiarize the students about phages and phage- bacterial interactions. Bacteriophages have been of intense value in elucidating many biological phenomena, including those concerned with genetics.

The course is organized as follows:

No.	Blocks	Units
1.	Bacteriophages	1. Historical prospective of bacteriophages 2. Biological processes of phage bacterial interaction 3. Life cycle of bacteriophages 4. Biotechnological Genetic manipulation

VI. Theory

Block 1: Bacteriophages

Unit 1: Historical prospective of bacteriophages.

Historical developments and classification of bacteriophages.

Unit 2: Biological processes of phage bacterial interaction

Physiology, biochemistry, enzymology and molecular biology of phage- bacterial interactions.

Unit 3: Life cycle of bacteriophages.

Structure, functions and life cycles of P2 phage, Lambda phage, M13 phage, ÕX174 phage.

Unit 4: Biotechnological Genetic manipulation

Phages in the development of molecular biology and genetic engineering.

VII. Practicals

- Titration of phages and bacteria.
- Absorption of phages.
- Preparation of phage stocks.
- Isolation of new phages and phage resistant bacteria.
- One step growth curve, phage bursts.
- Induction of lambda.
- Complementation of T_4*rII* mutantsetc.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work in Practical

IX. Learning outcome

With this course the students are expected to be able to learn

- About different phages and phage- bacterial interactions.
- Intensible value Bacteriophage in elucidating many biological phenomena, including those concerned with genetics.
- Development of molecular biology and genetic engineering

X. Suggested Reading

- Birge EA. 2000. *Bacterial and Bacteriophage Genetics*. Springer-Verlag. Mathew CK. 1972. *Bacteriophage Biochemistry*. Am. Chemical Soc.
- Mathew CK, Kutter EM, Mosig G & Berget P. 1988. *Bacteriophage T4*. Plenum Press.
- Nancy T and Trempy J. 2004. *Fundamental Bacterial Genetics*. Blackwell. Stent SG. 1963. *Molecular Biology of Bacterial Viruses*. WH Freeman and Co.
- Winkler J, Ruger W and Wackernagel W. 1979. *Bacterial, Phage and Molecular Genetics - An Experimental Course*. Narosa.
- Winkler U and Rugr W. 1984. *Bacteria, Phage and Molecular Genetics*. ALA.

Websites

- https://www.nature.com/scitable/definition/bacteriophage-phage-293
- https://www.phe-culturecollections.org.uk/news/nctc-news/the-rise-and-rise-of-bacteriophages. aspx

- https://www.khanacademy.org/science/biology/biology-of-viruses/virus-biology/a/bacteriophages

I. Course Title : Environmental Microbiology

II. Course Code : MICRO 509

III. Credit Hours : 2+1

IV. Why this Course?

This course deals with the study of composition and physiology of microbial communities in the environment. Diversity of microbial populations and their important roles in air, water, soils and sediments. Microbial community ecology and interactions with plants and animals. Microbial communities control nutrient cycles and transformation of compounds. Deeper understanding about the beneficial and harmful effects of microbial communities in the environment will help, so this course as been mandated.

V. Aim of the course

The course is designed to introduce students to diverse microbial population and their important roles in environmental processes in air, water, soils and sediments.types of microorganisms found in the air, terrestrial and aquatic environments. Interaction of microbial communities with plants and animals. Geochemically and environmentally significant processes that are contributed by the activities of microorganisms. Methods that are used to identify and enumerate bacteria in natural environments and also how specific microbial activities. Impact of microbial degradation of organic contaminants and xenobiotics.

The course is organized as follows:

No.	Blocks	Units
1.	Microbial ecology	1. Scope of Environmental microbiology and Ecological Niche 2. Microorganisms and their natural habitats 3. Extremophiles
2.	Microbial interaction	1. Biogeochemical cycles 2. Waste water and solid waste treatment 3. Microbial upgradation in fossil fuels and interaction in rumen and gastrointestinal tract

VI. Theory

Block 1: Microbial Ecology

Unit 1: Scope of Environmental microbiology and Ecological Niche

Scope of environmental microbiology,Microbial ecology: Microbial evolution and biodiversity – Ecological niches – Definitions, biotic and abiotic environment. Environmental segments. Composition and structure of environment. Concept of biosphere, communities and ecosystems. Ecosystem characteristics, structure and function. Food chains, food webs and trophic structures. Ecological pyramids.

Unit 2: Microorganisms and their natural habitats

Microorganisms and their natural habitats: Aeromicrobiology, Astrobiology, Methane and chlorates on Mars, terrestrial analogues. Biofilms and microbial mats, Aquatic ecosystems- Public Health Microbiology.

Unit 3: Extremophiles

Extremophiles: Definition and ecological aspects. Thermophiles, Xerophiles, Psychrophiles, Piezophiles, Alkaliphiles, Acidophiles- Halophiles and Barophiles. Environmental Distribution and Taxonomic Diversity, Physiology, Adaptive mechanisms, Enzymes, Applications.

Block 2: Microbial Interaction

Unit 1: Biogeochemical cycles

Biogeochemical cycling and its consequences. Global environmental problems.

Unit 2: Waste water and solid waste treatment

Microbiology of wastewater and solid waste treatment: - Waste-types-solid and liquid waste characterization, physical, chemical, biological, aerobic, anaerobic, primary, secondary and tertiary treatments. Anaerobic processes-Bioremediation of nuclear wastes. Bioconversion of Solid Waste and utilization as fertilizer. Bioaccumulation of heavy metal ions from industrial effluents. Biomining. Microbiology of degradation of xenobiotics in the environment, ecological considerations, decay behavior.

Unit 3: Microbial upgradation in fossil fuels and interaction in rumen and gastrointestinal tract.

Microbial upgradation of fossil fuels and coal gas. Microbial interaction in rumen and gastrointestinal tract.

VII. Practicals

- Determination of indices of pollution by measuring BOD/COD of different effluents.
- Analysis of natural waters.
- Quality control tests, waste treatment and anaerobic digestion; Demonstration of waste water treatment processes such as activated sludge processes, biofilter and fluidized bed process.
- Bacterial reduction of nitrate from ground waters.
- Isolation and purification of degradative plasmid of microbes growing in polluted environments.
- Recovery of toxic metal ions of an industrial effluent by immobilized cells.
- Utilization of microbial consortium for the treatment of solid waste [Municipal Solid Waste]
- Biotransformation of toxic metal ions into non-toxic metals ions.
- Microbial dye decolourization/adsorption.
- Biotrap based isolation of selective functional microbes.
- Thermophlic enzyme in biomass deconstructions.
- Halophilic microbes from salt lake-Pesticide degradation by microbes

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work in practical

– Field visit
– Case studies

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Appreciate the diverse microbial communities in environment and will be able to isolate and enumerate them from different environment.
– Realise the significance of microbial communities in biogeochemical cycles and their beneficial aspects to plants.
– Role of microorganism which are involved for bioremediation of harmful xenobiotic compounds.

X. Suggested Reading

- Campbell R. 1983. *Microbial Ecology*. Blackwell.
- Hawker LE & Linton AH. 1989. *Microorganisms Function, Form and Environment*. 2^{nd} Ed. Edward Arnold.
- Richards BN. 1987. *Microbes of Terrestrial Ecosystem*. Longman.
- Mitchell R. 1992. *Environmental Microbiology*. John Wiley & Sons.
- Baker K.H. and Herson D.S. 1994. *Bioremediation.* McGraw Hill Inc., N.Y.
- Metcalf and Eddy HP. 2004. *Waste Water Engineering - Treatment, Disposal and Re-use* Inc., Tata McGraw Hill, New Delhi.
- McEldowney S Hardman DJ and Waite S. 1993. *Pollution: Ecology and Biotreatment* Longman Scientific Technical.
- Mitchell R, and GuJi-Dong. 2010. *Environmental Microbiology*. John V, Wiley Sons. Inc.
- Waste Water Microbiology 2nd Edition. Bitton. Chemistry and Ecotoxicology of pollution. Edited by Des. W. Connell, G.J. Miller. Wiley Interscience Publications.
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- Connell OW and Miller GJ. 1984. *Chemistry and Ecotoxicology of pollution*. Wiley Interscience Publications.
- Forster CF and John Wase DA. *Environmental Biotechnology*. Ellis Horwood Ltd. Publication.
- Trivedi RK. 1998. *Advances in Waste Water Treatment Technologies*. Volumes II and I Global Science Publication.
- Lawrence P, Wacekett C and Hershberger D. 2000. *Biocatalysis and Biodegradation: Microbial transformation of organic compounds*. ASM Publications.
- Hurst CJ. 2001. *A Manual of Environmental Microbiology*. 2nd Edition. ASM Publications.

Websites

- http://microbiology.ucsc.edu.
- http://www.asm.org

I. Course Title : Industrial Microbiology

II. Course Code : MICRO 510

III. Credit Hours : 2+1

IV. Why this Course?

The syllabus of industrial microbiology is oriented towards the industrial application of microorganisms and recent microbial products. After studying this course students will know the industrial aspects of microbiology.

V. Aim of the course

To expose the students to the commercial exploitation of microorganisms for production of useful products. Focus will be on understanding of the techniques involved and the application of microorganisms for agribusiness purpose.

The course is organized as follows:

No.	Blocks	Units
1.	Basics of Industrial Microbiology	1. Historical account of microbes in industrial microbiology 2. Fermented Microbial products
2.	Bioplastics, Biopolymers & Biofuels	1. Biocontrol agents and Biopesticides 2. Industrial production of Bioplastics and biopolymers 3. Production of valuable products

VI. Theory

Block 1: Basics of Industrial Microbiology

Unit 1: Historical account of microbes in industrial microbiology

Introduction to Industrial Microbiology. Sources and characters of industrially important microbes; their isolation, purification and maintenance.
types of fermentation and fermenters. Microbial growth kinetics in batch, continuous and fed-batch fermentation process.

Unit 2: Fermented Microbial products

Bioreactors: Types and configuration. Microbiology and production of alcoholic beverages; Malt beverages, distilled beverages, wine and champagne; Commercial production of organic acids like acetic, lactic, citric, and gluconic acids Commercial production of important amino acids (glutamic acid, lysine and tryptophan), vitamins (riboflavin and vitamin A), enzymes, antibiotics and single cell proteins.

Block 2: Bioplastics, Biopolymers and Biofuels

Unit 1: Biocontrol agents and Biopesticides

Biocontrol agents and Biopesticides: Biocontrol agents and their scope in control of plant diseases, nematodes and insect pests. Role of bioagents in sustainable agriculture.

Unit 2: Industrial production of Bioplastics and biopolymers

Introduction & industrial production of Bioplastics: Microorganisms involved in synthesis of biodegradable plastics and microbial pigments and biopolymers.Biosensors: Development of biosensors to detect food contamination and environment pollution. Biofuels: Production of ethanol, biogas and hydrogen from organic residues, fuels from algae; Mushroom cultivation.

Unit 3: Production of valuable products

Genetic engineering of microbes, Role of recombinant microbes in industrial sectors for enhanced production of valuable products. Mechanisms of pesticide degradation by microbes. Biomining: Coal, mineral and gas formation, prospecting for deposits of crude, oil and gas, recovery of minerals from low-grade ores.

VII. Practicals

- Isolation and purification of industrially important microbes (Bacteria, fungus and yeasts)
- Production of industrial compounds such as alcohol, beer, citric acid, lactic acid

acetic acids gluconic acid and their recovery
- Demonstration of biogas production
- Production and assay of enzymes, organic acids and pigments
- Mass production of biocontrol agent
- Visit to industries

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work in Practical
- Field visit/Industries/University lab
- Case studies

IX. Learning outcome

After studying this course students will know and will be able to learn

- The applied and industrial aspects of microbiology such as screening of microorganisms, strain improvement, microbial metabolites, fermented microbial products, microbial enzymes, Biofuels using microbes and microbial production of Biopolymers.
- The recent applications of the microbes for the human welfare.

X. Suggested Reading

- Sylvia DM, Fuhrmann JJ, Hartlly PT and Zuberer D. 2005. *Principles and Applications of Soil Microbiology*. 2nd Ed. Pearson Prentice Hall Edu.
- Waites, M.J., Morgan, N.L., Rockey, J.S. and Higton, G. (2002). *Industrial Microbiology: An Introduction.* Blackwell Science Publishers.
- Crueger W and Crueger A. *Biotechnology: A Text Book of Industrial Microbiology* Panima Publishing Corporation.
- Reed G. 1999. *Prescott and Dunn's Industrial Microbiology*. CBS Publishers.
- Demain AL. 2001. *Industrial Microbiology and Biotechnology* IInd Edition. ASM Press, Washington.
- Stanbury PF, Whitaker W and Hall SJ. 1997. *Principles of Fermentation Technology* Aditya Books (P) Ltd., New Delhi.
- Baltz RH, Davies JE and Demain AL. 2010. *Manual of Industrial Microbiology and Biotechnology*. 3rd Edition, ASM Press.
- Forciniti D. 2008. *Industrial Bioseparations: Principles and Practice*. 1st Edition, Wiley-Blackwell.
- OkaferN. 2007. *Modern Industrial Microbiology and Biotechnology,* Scientific Publishers, Enfield, USA.
- Nduka O and Benedict OC. 2018. *Modern Industrial Microbiology and Biotechnology*, Taylor and Francis 465p.
- ElMansi EMT, Bryce CFA, Dahhou A, Sanchez S, Demain AL, Allman AR. 2012. *Fermentation Microbiology and Biotechnology* 3rd Ed. CRC Press, Taylor and Francis, Boca Raton.
- Stanbury AF and Whitaker A. 1984. Principles of Fermentation Technology –Oxford Pergamon press New York.
- Moses V and Cape RE. 1991. *Biotechnology* - The Science and the Business Harwood Academic Publishers, USA.
- Casida LE Jr. 1989. *Industrial Microbiology* Wiley Eastern Ltd., N. Delhi.
- Miller BM and Litsky W. 1976. *Industrial Microbiology*, McGraw Hill Co.,New York 451p.
- Crueger W and Crueger A. 1984. *Biotechnology – a Text book of Industrial Microbiology*. Science Tech. Inc., Madison.
- Glazer AN and Nikaido HN. 1995. *Microbial Biotechnology: Fundamentals of Applied Microbiology*, W.H.Freeman Co., New York.

- Demain AL and Solomon MA. 1986. *Manual of Industrial Microbiology and Industrial Microbiology*, American Society of Microbiology, Washington.
- Atkinson B and Marituna F. 1983. *Biochemical Engineering and Biotechnology* Handbook, McMillian Publishers.
- Jones DG. 1983. *Exploitation of Microorganisms*. Chapman & Hall, Oxford.
- Peppler HJ and Perlman D. 1979. Microbial technology Vol.1 Fermentation Tecnology, Vol.2, Academic Press.
- Rehm HJ and Reed G. 1995. *Biotechnology, a Comprehensive Treatise*, 8 Vols. (Reference Book) Verlag Chemie,Wienheim. Also refer Second edition, 12 vols,1995 (Rehm,H.J.: Reed, G.: Puhler,A; Stadler, P Eds)
- Moo-Young Y. 1985. *Comprehensive Biotechnology*- 5 vols. (Reference Book) Pergamon Press, Oxford.
- Arora DK. 1992. *Handbook of Applied Mycology* – 5 Vols. (Reference Book) Marcel Dekker, New York.
- Glick BR and Pasternak JJ. 2003. *Molecular Biotechnology-principles and applications of recombinant* DNA,ASM press,Washington,760 pp.

Also consult latest issues of:

- Advances in Applied Microbiology, Biotechnology Advances,
- Biotechnology & Genetic Engineering Reviews,Advances in Biochemical Engineering & Biotechnology, Advances in Microbial Physiology

Websites

- https://www.biomerieux.com/en/industrial-microbiological-control-0
- https://icar.org.in/content/food-and-industrial-microbiology

I. Course Title	:	**Biofertilizer Technology**
II. Course Code	:	**MICRO 511**
III. Credit Hours	:	**2+1**

IV. Why this Course?

The exploitation of beneficial microbes as a biofertilizer is of prime importance in agriculture sector for their potential role in food safety and sustainable crop production. There is wide gap between nutrient removal and supplies. There is increase in cost of fertilizers due to deplete in the feed stock fossil fuels besides growing concern of environmental hazards due to chemical fertilizers. It is essential to exploit Biofertilizers having functional traits for enhancing plant growth and productivity, nutrient profile, plant defense and protection with special emphasis to its function to trigger various growth- and defense-related genes in signaling network of cellular pathways to cause cellular response and thereby crop improvement.

The syllabus Biofertilizers technology is oriented towards application of biofertilizer to trap atmospheric nitrogen to the soil and convert them into plant usable forms. They also convert the insoluble phosphate forms into plant available forms. They stimulate root growth by producing some hormones and antimetabolites. Improved Plants.

V. Aim of the course

To familiarize the students and farmers with mass scale production of different agriculturally important microorganisms which are being used as biofertilizers for maintaining the soil and plant health for sustaining crop productivity and their importance in organic farming.

The course is organized as follows:

No.	Blocks	Units
1.	Agriculturally important beneficial microorgansims	1. Agriculturally important beneficial nitrogen fixing microorganisms. 2. Agriculturally important beneficial microorganisms related to phosphorous, potassium, Sulphur and Zinc nutrition 3. Agriculturally important beneficial microorganisms having plant growth promoting rhizobacteria 4. Agriculturally important biocontrol microbial inoculants 5. Economics of biofertilizer production.
2.	Production of Biofertilizer	1. Production and quality control of biofertilizer

VI. Theory

Block 1: Agriculture Important Beneficial Microorganisms

Unit 1: Agriculturally important beneficial nitrogen fixing microorganisms.

Different agriculturally important beneficial microorganisms: Chemical Vs Biofertilizers: Current Scenario in biofertilizer technology in world-In India-List of biofertilizers-their applications in agriculture.

Brief introduction about Agriculturally beneficial microorganisms (free living, symbiotic (rhizobial, actinorhizal), associative and endophytic nitrogen fixers including phosphobacteria, cyanobacteria, their types and importance taxonomic classification, Nitrogen fixing biofertilizers: nodule formation, competitiveness and quantification of N_2 fixed and their use. Mechanism of phosphorous solubilization by photobacteria. BIS standards of biofertilizers

Unit 2: Agriculturally important beneficial microorganisms related to phosphorous, potassium, Sulphur and Zinc nutrition

Different agriculturally important beneficial microorganisms: phosphate solubilizing bacteria and fungi, including mycorrhiza; Mechanism of phosphorous solubilization by phosphobacteria. Bacteria for potassium, Sulphur and Zinc nutrition.

Unit 3: Agriculturally important beneficial microorganisms having plant growth promoting rhizobacteria.

Different agriculturally important beneficial microorganisms: plant growth promoting rhizobacteria. FCO norms and biofertilizer production and usage at national and international levels

Unit 4: Agriculturally important biocontrol microbial inoculants

Different agriculturally important beneficial microorganisms: Biocontrol microbial inoculants. Requirements for establishing bioinoculants production unit Economics of biofertilizers production Constraints in biofertilizers production and usage

Unit 5: Economics of biofertilizer production

Different agriculturally important beneficial microorganisms for recycling of organic waste and compositing, bioremediators and other related microbes.

Block 2: Production of Biofertilizer

Unit 1: Production and quality control of biofertilizer

Different agriculturally important beneficial microorganisms - selection, establishment, competitiveness, crop productivity, soil & plant health, mass scale production and quality control of bio inoculants. Biofertilizer inoculation and microbial communities in the soil. Different formulations of biofertilizers. Advantages and limitations of Liquid formulations.

VII. Practicals

- Isolation of phosphate solubilizing microorganisms.
- Development and production of efficient microorganisms,
- Determination of beneficial properties in important bacteria to be used as biofertilizer, Nitrogen fixing activity, indole acetic acid (IAA), siderophore production etc,
- Bioinoculant production and quality control.
- Population dynamics in broth and carrier materials during storage.
- Development of cultures from starter.
- Preparation of broth for large scale cultivation in fermenter/ large containers. Inoculation and development of culture.
- Mass production of carrier based and liquid biofertilizers. Mass production of important two or three biocontrolagents (*Trichoderma viride, Pseudomonas fluorescens* and *Metarhiziumanisopliae*).
- Form, dose and method of application.
- Mass production of AM fungi in pot and root organ culture.
- Quality control and BIS standards.
- Mass production of Azolla and BGA.
- Visit to a biofertilizer production plant

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures
- Review of policy documents

IX. Learning outcome

After successful completion of this course, the students are expected to be able to learn:

- Agriculturally important beneficial microorganisms for fixation of various important elements and compounds.
- Biofertilizer production and usage at national and international levels.
- Requirements for establishing bioinoculants production unit, economics (solid liquid carrier) production, constraints in biofertilizers production and usage.
- A complete exposure to all kinds of agriculture important biofertilizers along with their functions and properties,
- Helps to develop as entrepreneur.

X. Suggested Reading

Books

- Alexander M. 1977. *Soil Microbiology*. John Wiley.
- Bergerson FJ. 1980. *Methods for Evaluating Biological NitrogenFixation*. John Wiley & Sons.
- Sylvia DM, Fuhrmann JJ, Hartlly PT and Zuberer D. 2005. *Principles and Applications of Soil Microbiology*. 2nd Ed. Pearson Prentice Hall Edu.
- Van Elsas JD, Trevors JT and Wellington EMH. 1997. *Modern Soil Microbiology*. CRC Press.
- Panwar JDS and Jain AK. 2016. *Organic farming scope and use of biofertilizers*. Pub: NIPA, New Delhi.
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- DeshMukh AM, Khobragade RM and Dixit PP. 2007. *Handbook of Biofertilizers & Biopesticides*. Oxford Book Company, Jaipur, India.
- Gupta RP, Kalia A and Kapoor S. 2007. *Bioinoculants a Step towards Sustainable Agriculture* .NIPA, New Delhi.
- Somani LL, Shilkar P and Shilpkar D. 2011. *Biofertilizers Commercial Production Technology & Quality Control*. AgroPublishing Acadamy, Udaipur.
- Srivastava HS and Singh RP. 1995. *Nitrogen nutrition in higher plants*. Associated Publishing Company, New Delhi.
- Kannaiyan S and Kumar K. 2005. *Azollabiofertiliser for sustainable Rice Production*. Daya Publishing House, Delhi.
- Kannaiyan S, Kumar K and Govindarajan K. 2010. *Biofertilizer Technology*. Scientific Publishers (India), Jodhpur.
- Vora MS, Shelat HN and Vyas RV. 2013. *Handbook of Biofertilizers & Microbial Pesticides*.
- Chanda JK. 2008. *Biofertilizer Statistics 2006-07*. The fertilizer Association of India, New Delhi.

Journals

- *Journal of Biofertilizer& Biopesticides*
- *Journal of Botanical Sciences*

Websites

- Biofertilizer in organic Agriculture (www.Journalphytology.com)
- Microbial biofertilizers (www.Boffinaccess.com)
- Biofertilizer as a prospective input for sustainable agriculture in India. http://www.krishisewa.com/articles/organic-agriculture/115-biofertilizers.html
- Handbook of Microbial Biofertilizers M. K. Rai, PhD Editor Pub: Food Products Press, NY.
- Bio fertilisers https://www.worldcat.org/search?q=biofertilisers&fq=dt%3Abks&dblist=638&qt =sort&se=yr&sd=desc&qt=sort_yr_desc

I. Course Title : Cyanobacterial and Algal Biotechnology

II. Course Code : MICRO 512

III. Credit Hours : 2+0

IV. Why this Course?

Cyanobacteria and algal biomass contribute major role in carbon cycle in turn influencing the climate. The blooms of cyanobacteria and algae in different ecosystems is worth exploiting due to their wide biodiversity. They play an important role in agriculture by contributing to the fertility of soil in terms of biomass, biofertilizer, and act as herbicides, insecticides and in bioremediation. Their physiological and biochemical properties disclose their significant potential for colorants, polysaccharides, pharmaceutical & nutraceutical compounds, and valuable biomolecules of industrial importance. With the population explosion and scarcity of land, these can provide better feed stock due to their high protein content, easy cultivation, and versatile growth and easy to harvest. It is challenging for designing bioreactor and utilizes waste waters for growing and harvesting cyanobacteria and algae for these purposes. They are capable of producing and accumulating lipids which can be the source for biodiesel in future.

This course will help the student to understand taxonomy and molecular biology methods of cyanobacteria. The course will give knowledge on cyanobacterial and algal fuels,

V. Aim of the course

The aim is togive exposure on the potential applications of cyanobacteria and algae in Agriculture, Industry and Environment; to inculcate knowledge on algal mass production techniques and their valuable products of commercial importance and to introduce the R&D and entrepreneurial opportunities algae. Students will learn about biodiversity of cyanobacteria and their classification**, t**he biotechnological applications in agriculture – biofertilizers, biocontrol, bioenergy and bioprocessing, their applications in pharmaceuticals, production of antioxidative enzymes and pigments, as source of food, etc.

The course is organized as follows:

No.	Blocks	Units
1.	Importance of cyanobacteria and algae	1. Ecology and evolution of algae and cyanobacteria
2.	Physiology and culturing of cyanobacteria and algae	1. Algal pigments, storage products 2. Metabolism of carbon and nitrogen 3. Culturing methods.
3.	Role of cyanobacteria and algae in agriculture and their products of industrial importance	1. Importance as fuels, neutraceuticals and industrial importance 2. Role of algae related to environment

VI. Theory

Block 1: Importance of Cyanobacteria and Algae

Unit 1: Ecology and evolution of algae and cyanobacteria

Introduction to cyanobacteria and algae. Definition, occurrence and distribution, thallus structure, reproduction, life cycles, origin and evolution of cyanobacteria, molecular evolution; role of algae in evolution of land plants and horizontal transfer of genes. Brief classification of algae: different classes, occurrence and distribution.

Block 2: Physiology and Culturing of Cyanobacteria and Algae

Unit 1: Algal pigments, storage products.

Algal pigments, storage products, physiology and metabolism including photosynthesis.

Unit 2: Metabolism of carbon and nitrogen

Ecology of algae –primary colonizers and cycling in soil and water. Cellular differentiation and nitrogen fixation, nitrogen metabolism carbon metabolism.

Unit 3: Culturing methods

Algal culturing and cultivation. Culture types, culture conditions, culture vessels, culture media, sterilization, culture methods, synchronous cultures, photobioreactors, algal density and growth, seaweed cultivation.

Block 3: Role of Cyanobacteria and Algae in Agriculture and their Products of Industrial Importance

Unit 1: Importance as fuels, neutraceuticals and industrial importance.

Cyanobacterial and algal fuels, Fine chemicals (restriction enzymes etc.) and nutraceuticals from algae; UV absorbing pigments Industrial products from macro algae - seaweed biotechnology, sustainable aquaculture. Ecology of algae- distribution in soil and water; primary colonizers, carbon sequestration and cycling in soil and water. Cellular differentiation and nitrogen fixation, nitrogen metabolism.

Unit 2: Role of algae related to environment.

Algae in pollution control - as pollution indicators, eutrophication agents and role in Bioremediation and reclamation of problem soils. Cyanobacterial and algal toxins, allelopathic interactions, Algae in global warming and environmental sustainability. Cyanobacteria and selected microalgae in agriculture – biofertilizers &algalization; soil conditioners; reclamation of problem soils.

VII. Teaching methods/activities

– Lecture
– Assignment (reading/writing)
– Publication review
– Student presentation
– Group discussion
– Case analysis and case studies
– Guest lectures

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Types of cyanobacteria and algae along with their physiological and biochemical properties that provides base for selection for further exploitation of industrial use.
– Algal culturing and cultivation. Culture types, culture conditions, synchronous cultures, photobioreactors, algal density and growth, seaweedcultivation.
– Production of cyanobacterial and algal fuels
– Industrial products from macro algae – seaweed biotechnology, sustainable aquaculture.
– Ecology of algae – distribution in soil and water; primary colonizers, carbon sequestration and cycling in soil and water.

IX. Suggested Reading

- Ahluwalia AS. 2003. *Phycology: Principles, Processes and Applications*. Daya Publ.
- Barsanti L and Gualtieri P. 2006. *Algae: Anatomy, Biochemistry and Biotechnology*. Taylor & Francis, CRC Press.
- Carr NG and Whitton BA. 1982. *The Biology of Cyanobacteria*. Blackwell.
- Herrero A and Flores E. 2008. *The Cyanobacteria Molecular Biology,Genomics and Evolution*. Calster Academic Press

- Kumar HD. 2005. *Introductory Phycology*. East West Press. Linda E Graham & Lee W Wilcox. 2000. *Algae*. Prentice Hall.
- Andersen RA. 2005. *Algal Culturing Techniques*. Academic Press.
- Venkataraman LV and Becker EW. 1985. *Biotechnology and Utilization of Algae: the Indian Experience*. DST.
- Das MK. 2010. *Algal Biotechnology*. Daya Publishing House.
- Tiwari. 2014. *Cyanobacteria: Nature, Potentias and Applications*. Daya Publishing House.
- Khattar JIS, Singh DP, Kaur G. 2009. *Algal Biology and Biotechnology*. I.K. International Publishing HousePvt. Ltd.
- Bhatnagar SK, Saxena A, Kraan S. 2011. *Alga Biofuels*. Stadium Press (India) Pvt. Ltd.
- Sahoo D and Kaushik BD. 2012. *Algal Biotehcnolgoy and Environment*. I.K. International Publishing HousePvt. Ltd.

Journals

- *Journal of Phycology*
- *Journal of Applied Phycology*
- *Frontiers in Microbiology*

Websites

- Cyanbacterial and algal Biotechnology
- https://www.worldcat.org/search?q=cyanobacterial+and+algal+biotechnology&qt=results_page#%2528x0%253Abook%2Bx4%253Aprintbook%2529format
- www.cyanosite.bio.purdue.edu
- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.bbsrc.ac.uk/organisation/policies/reviews/scientific-areas/1107-algal-research.aspx
- http://asulightworks.com/resources/videos/arizona-center-algae-technology-and-innovation.html

Course Title with Credit load
Ph.D. in Microbiology

Course Code	Course Tittle	Credit Hours
MICRO 601*	Improvement in fermentation Technology	2+1
MICRO 602	Microbial physiology and regulation	2+0
MICRO 603*	Recent development in soil microbiology	2+0
MICRO 604	Recent approaches in environmental microbiology	2+0
MICRO 605*	Plant microbe interactions	2+1
MICRO 691	Doctoral seminar I	1+0
MICRO 692	Doctoral seminar II	1+0
MICRO 699	Doctoral Research	75

*Core Courses

Course Contents
Ph.D. in Microbiology

I. Course Title : Improvements in Fermentation Technology
II. Course Code : MICRO 601*
III. Credit Hours : 2+1

IV. Why this Course?

This course aims to introduce technological advancement of fermentation and bioprocess for industrial applications. Microorganisms are capable of growing on a wide range of substrates and can produce a remarkable spectrum of products. This course will enlighten the students on basics of fermentation, metabolic engineering, fermenter design and downstream processing. The economics of industrial products are introduced to understand commercialization of microbial products.

V. Aim of the course

The aim is to teach students regarding fermentation industry using industrially useful microorganisms including yeast technology. To introduce the students to broad coverage of a diverse field of fermentation technology, provide an understanding of the exploitation of microorganisms in the manufacture of bio products and provide the students with skill in operation of fermenter.

The course is organized as follows:

No.	Blocks	Units
1.	Rise of Fermentation Technology	1. Development in Fermentation 2. Types of Fermenters
2.	Fermenter	1. Component of fermenter and use
3.	Fermentation process	1. Types of Fermentation
4.	Recombinant Strategies Followed	1. Strategies for isolation of industrially important microbes

VI. Theory

Block 1: Rise of Fermentation Technology

Unit 1: Development in Fermentation

Definition of fermentation – rise of fermentation technology –current trends in fermentation industry – scope and importance of fermentation technology.

Unit 2: Types of fermenters

Continuous, batch and fed batch culture –anaerobic fermentation - range of fermentation process – microbial growth cycle – diauxic growth – growth kinetics – substrate uptake kinetics (Jacob and Monod) - primary and secondary metabolites – future prospects of fermentation microbiology

Block 2: Fermenter

Unit 1: Components of fermenter and use

Peripheral parts and accessories – alternative vessel designs –containment in fermentation – fermenter preparation and use - aeration and agitation – instrumentation and control – biosensors in monitoring – computer applications in fermentation technology

Block 3: Fermentation Process

Unit 1: Types of Fermentation

Solid state and submerged fermentation – acidic/alcoholic fermentation - recovery of product – effluent treatment – Economics of fermentation

Block 4: Recombinant Strategies Followed

Unit 1: Strategies for isolation of industrially important microbes

New strategies for isolation of industrially important microbes and their genetic manipulations; Antibiotic fermentation research; steroid transformation; Yeast technology – classification, genetics, strain improvement for brewing, baking and distilleries

VII. Practicals

- Studying the various components of fermenter
- exposure to different types of fermenter
- sterilization and operating procedures
- designing the production medium
- isolation and purification of industrially important microbes
- Genetic manipulations in microbes
- Fermentation by improved strains of yeast for production of alcohol
- microbial production of enzymes by solid state fermentation
- Microbial production of important antibiotics
- Bioremediation of industrial effluents

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Publication Review
– Student presentation
– Group discussion
– Case Analysis and case studies
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Students should have an understanding of the variety of fermentation and subsequent processing approaches available for the manufacture of biological products and the design and operation of these systems.

X. Suggested Reading

- Stanbury PF, Whitaker A and Hall SJ. *Principles of fermentation technology*, Second edition
- Patel AH. *Industrial Microbiology*
- ElMansi EMT and Bryce CFA. *Fermentation Microbiology and Biotechnology*

- Srivastava ML. *Fermentation Technology*
- Singh T and Purohit SS. *Fermentation Technology*
- ElMansi EMT, Bryce CFA, Demain AL and Allman AR. *Fermentation Technology – Microbiology and Biotechnology*
- Peppler HJ and Perlman D. 1979. *Microbial Technology*. 2nd Ed. Academic Press.
- Reed G. 1987. *Presscott& Dunn's Industrial Microbiology*. 4th Ed. CBS.
- Stanbury PF and Whitaker A. 1987. *Principles of Fermentation Technology*. Pergamon Press.
- Wiseman A. 1983. *Principles of Biotechnology*. Chapman & Hall.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.scribd.com/doc/46151150/Fermentation-Technology
- http://www.chalmers.se/en/areas-of-advance/lifescience/research/Pages/Fermentation-Technology.aspx

I. Course Title : Microbial Physiology and Regulation

II. Course Code : MICRO 602

III. Credit Hours : 2+0

IV. Why this Course?

Microorganisms have tremendous metabolic diversity hence it's intriguing to learn how these small creatures deal with different environmental conditions and either adopt themselves to it or convert it to favorable conditions by involving different physiological processes. The contents of this course will help students how microbes can grow on substrates other than glucose, their inorganic metabolism and biosynthesis and how do they respond to the changes in environment

V. Aim of the course

To acquaint students with current topics in molecular microbiology. Course imparts thorough knowledge about the synthesis of biomolecules in microorganisms by various pathways and their regulation.

The course is organized as follows:

No.	Blocks	Units
1.	Historical evaluation of microbial physiology	1. Molecular aspects of various cell component
2.	Regulation and pathways	1. Regulatory Pathways 2. Regulatory control 3. Current topics

VI. Theory

Block 1: Historical Evaluation of Microbial Physiology

Unit 1: Molecular aspects of various cell component

Origin, evolution, structure, function and molecular aspects of various cell components. Differentiation in bacteria, slime molds, yeasts. Molecular biology of bioluminescence, bacterial virulence. Heat shock response. Extracellular protein secretion in bacteria.

Block 2: Regulation and Pathways

Unit 1: Regulatory Pathways

Regulation of initiation, termination and anti-termination of transcription. Global regulation and differentiation by sigma factor. Regulatory controls in bacteria - inducible and biosynthetic pathways. Oxidative stress control. Fermentative and respiratory regulatory pathways.

Unit 2: Regulatory control

Ribosomal RNA and ribosomal proteins regulation under stress condition. Specific regulatory systems; SOS regulatory control; Antisense RNA regulation of gene expression.Biosynthesis of micromolecules (Nucleotides and Aminoacids) macromolecules (DNA, RNA, Proteins) Global nitrogen control and regulation of nitrogen fixation

Unit 3: Current topics

Topics of current interest in Molecular microbiology and regulatory systems.

VII. Teaching methods/activities

– Class room Lecture
– Assignment (Reading/Writing)
– Student presentation
– Seminar presentation by students

VIII. Learning outcome

With this course, the students are expected to be able to learn
– Current topics in molecular microbiology.
– Thorough knowledge about the synthesis of biomolecules in microorganisms by various pathways and their regulation.
– About the synthesis of biomolecules in microorganisms by various pathways and their regulation.

IX. Suggested Reading

Websites

- https://www.frontiersin.org/journals/microbiology/sections/microbial-physiology-and-metabolism
- https://www.sciencedirect.com/bookseries/advances-in-microbial-physiology
- https://www.researchgate.net/journal/0065-2911_Advances_in_Microbial_Physiology
- https://bmb.psu.edu/undergraduate/courses/course-archive/2016/fall-2016/microbiology-micrb/micrb-401-fall-2016/micrb-401-microbial-physiology-and-structure
- Selected articles from journals.

I. Course Title : Recent Developments In soil microbiology
II. Course Code : MICRO 603*
III. Credit Hours : 2+0

IV. Why this Course?

Directly or indirectly the waste of human and other animals, their bodies, and the tissues of plants are dumped onto or buried in the soil. It is the microbes that make these changes –the conversion of organic matter in to simple organic substances that provide the nutrient material for the plant and agriculture world. Thus microorganisms play a vital role in maintaining life on earth. The prerequisite for this class is SOIL. To be completely prepared for this class a course taken in Microbiology is very useful.

V. Aim of the course

To make students learn the latest trends in soil microbiology like diversity, biological control and bioremediation.

The course is organized as follows:

No.	Blocks	Units
1.	Recent developments in soil microbiology	1. Ecology and microorganisms diversity 2. Role of microorganisms in soil 3. Bioremediation

VI. Theory

Block 1: Recent Developments in Soil Microbiology

Unit 1: Ecology and microorganisms diversity

Molecular ecology and biodiversity of soil microorganisms; Survival and dispersal of microorganisms. Interaction between agricultural chemicals, pollutants and soil microorganism

Unit 2: Role of microorganisms in soil

successions and transformation of organic matter; Role of microorganisms in soil fertility. Soil health and quality: Microbial indicators

Unit 3: Bioremediation

Bioremediation of polluted soils; Biological control. Other topics of current interest.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Seminar presentation by students.
- Case studies

VIII. Learning outcome

With this course, the students are expected to be able to learn

- Latest trends in soil microbiology like diversity, biological control and bioremediation.

IX. Suggested Reading

Websites

- https://www.springer.com/in/book/9789811073793
- https://www.researchgate.net/publication/322952969_Advances_in_Soil_Microbiology_Recent_ Trends_and_Future_Prospects_Volume_2_Soil-Microbe-Plant_Interaction
- Selected articles from journals.

I. Course Title : Recent Approaches in Environmental Microbiology

II. Course Code : MICRO 604

III. Credit Hours : 2+0

IV. Why this Course?

The activities of the microorganisms at large in nature/ environment are considered in this course. Microbes play far more important roles in nature than their small sizes would suggest. In order to evaluate the roles of microorganisms in ecosystems, it is essential to understand the precise natural habitats and how their activities can be explored.

V. Aim of the course

To apprise the students about the role of microbiology in environment management for sustainable eco-system and human welfare.

The course is organized as follows:

No.	Blocks	Units
1.	Recent environmental issue	1. Basic concepts and environmental issues 2. Methodology of environmental management 3. Microbial waste treatment.
2.	Energy harnessing from organic waste	1. Pollution through conventional fuel 2. Renewable sources of energy.
3.	Treatment of waste for safe disposal.	1. Disposal of domestic and industrial wastes 2. Global environmental problems

VI. Theory

Block 1: Recent Environmental Issue

Unit 1: Basic concept and environmental issues

Types of environmental pollution; problems arising from high-input agricultural residues. Air and water pollution.

Unit 2: Methodology of environmental management

Waste water treatment -physical, chemical, biological and microbial processes; need for water and natural resource.

Unit 3: Microbial waste treatment

Microbiology and use of micro-organisms in waste treatment; biodegradation; degradation of Xenobiotic, surfactants; bioremediation of soil & water contaminated with oils, pesticides & toxic chemicals, detergents, etc.; aerobic processes (activated sludge, oxidation ditches, trickling filter, rotating drums, etc.); anaerobic processes: digestion, filtration, etc.

Block 2: Energy Harnessing from Organic Waste

Unit 1: Pollution through conventional fuel

Conventional fuels and their environmental impact.

Unit 2: Renewable sources of energy.

Energy from solid waste; ; biogas; land filling, microbial hydrogen production; use of agro-industrial waste, agricultural waste for sugar to alcohol; gasohol; biodegradation of lignin and cellulose; biopesticides; biofertilizers; composting; vermiculture, etc.

Block 3: Treatment of Waste for Safe Disposal

Unit 1: Disposal of domestic and industrial wastes.

Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by micro-organisms.

Unit 2: Global environmental problems

Ozone depletion, UV-B, greenhouse effects, and acid rain; biodiversity and its conservation; Microbial and biotechnological approaches for the management of environmental problems.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Seminar presentation by students.
– Case studies

VIII. Learning outcome

With this course, the students are expected to be able to learn

– Latest trends in environmental microbiology like Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by micro-organisms
– Renewable and non-Renewable resources of energy; energy from solid waste; conventional fuels and their environmental impact; biogas; land filling, microbial hydrogen production

IX. Suggested Reading

- Evans GM and Furlong JC. 2002. *Environmental Biotechnology: Theory and Application*. Wiley International.
- Jordening HJ and Winter J. 2006. *Environmental Biotechnology: Concepts and Applications*. Wiley-VCH Verlag.

Websites

- https://www.springer.com/series/11961
- http://microbiology.ucsc.edu.
- http://www.asm.org

I. Course Title : Plant Microbe Interactions

II. Course Code : MICRO 605*

III. Credit Hours : 1+1

IV. Why this Course?

In the course, interactions between plants and microbes are discussed on general and detailed level for both pathogenic and symbiotic interactions. This course will be helpful in imparting knowledge to student about Infection mechanisms, defense of plants and stress responses and a large number of important problems within agriculture, horticulture and forestry

V. Aim of the course

The aim is to familiarize the students with the biochemical and biophysical mechanisms, genetics, genomics, proteomics and advanced microscopy, spectroscopy of different interfaces of beneficial and pathogenic plant microbe interactions. Molecular analysis of relevant factors in the plant and microbes, and components that modulate plant-microbe interactions for soil and plant health for sustaining crop productivity.

The course is organized as follows:

No.	Blocks	Units
1.	Types of ecosystem and microbial interaction	1. Different interfaces of interactions 2. Ecosystem- Concept and Dynamics.
2.	Signaling and interaction among microbes	1. Microbial interaction.
3.	Genomic and proteomic study in plant microbe interaction	1. Methodology/resources in plant-microbe interaction.

VI. Theory

Block 1: Types of Ecosystem and Microbial Interaction

Unit 1: Different interfaces of interactions

Plant-microbe, microbe-microbe, soil- microbe, soil-plant-microbe interactions leading to symbiotic (rhizobial and mycorrhizal, *Azolla-Anabaena*), associative, endophytic and pathogenic interactions.

Unit 2: Ecosystem- Concept and Dynamics

Types of ecosystems: Concept and dynamics of ecosystem, Food chain and energy flow, Microbial communities in the soil. Community dynamics and population interactions employing DGGE, TGGE, T-RFLP.

Block 2: Signaling and Interaction among Microbes

Unit 1: Microbial interaction

Quorum-sensing in bacteria, flow of signals in response to different carbon or other substrates and how signals are recognized.

Block 3: Genomic and Proteomic Study in Plant Microbe Interaction

Unit 1: Methodology/resources in plant-microbe interaction

Methodology/resources to study plant-microbe interaction, biosensors, transcriptome profiling, metabolic profiling, genomics, and proteomics Induced systemic resistance against pathogens and tolerance against abiotic stress: Molecular basis; Molecular diversity of microbes, plants and their interactions including transgenic microbes and plants

VII. Practicals

- Phylochip based microbial community analyses-
- Endophytic and phyllosphere microbial community
- PCR-DGGE-Rhizosecretion
- secretome -FT-IR, HPLC
- Multifunctional protein identification and characteriation-2DE, MALDI-TOF.
- Examination of mycorrhizal infection in roots of different plants.
- Characterization of PGPR; Quantification of siderophores, HCN and IAA

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation

– Group discussion
– Case Analysis and case studies
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to: Better understanding of soil – plant – microbe interaction and how the plant/ microbial system select their host. In addition this course will also provide new insight about the various biomolecules secreted by the plant root as well as microbes which forms the basis for their intimate association and exert multiple benefits to the plants.

X. Suggested Reading

- Kosuge T and Nester, E.W. 1989. *Plant Microbe Interactions: Molecular and Genetic Perspectives*, Vol.I-IV, McGraw Hill.
- Paul Eldor, A. 2007. *Soil Microbiology, Ecology and Biochemistry*
- Robert L. Tate III. 1995. *Soil Microbiology*, John Wiley & Sons, INC.
- Sylvia David, M., Fuhrmann, T.A., Hartel, P.G. and Zuberer, D.A. 2005. *Principles and Applications in Soil Microbiology* (II nd Edition).
- Verma, D.P.S. and Kohn, T.H. 1984. *Genes involved in Microbe-Plant Interactions*, Springer-Verlag
- Jaya Kumar Arjun, Kumarapillai Harikrishnan. 2011. Metagenomic analysis of bacterial diversity in the rice rhizosphere soil microbiome. *Biotechnol. Bioinf. Bioeng*. 1(3): 361-367
- Andrea Porras-Alfaro and Paul Bayman.2011. Hidden Fungi, Emergent Properties: Endophytes and Microbiomes. *Annu. Rev. Phytopathol*. 49: 291-315.
- Eleonora Rolli *et al*. 2014. Improved plant resistance to drought is promoted by the root-associated microbiome as a water stress-dependent trait. *Environmental Microbiology*. doi: 10.1111/1462-2920.12439
- Roeland L. Berendsen, Corne´ M.J. Pieterse and Peter A.H.M. Bakker. 2012. The rhizosphere microbiome and plant health. *Trends in Plant Science*, Vol. 17, No. 8.
- Josep Penuelas and Jaume Terradas. 2014. The foliar microbiome. *Trends in Plant Science*. http://dx.doi.org/10.1016/j.tplants.2013.12.007

Journals

- *Advances in Microbial Physiology*
- *Annual Review of Genetics/Biochemistry*
- *Annual Review of Microbiology*
- *Applied and Environmental Microbiology*
- *Biology and Fertility Soils*
- *Indian Journal of Microbiology*
- *Journal of Bacteriology*
- *Journal of Basic Microbiology*
- *Microbiology and Molecular Biology Reviews*
- *Nature/Science/EMBO Journal*
- *Reviews in Microbiology and Biotechnology*
- *Soil Biology and Biochemistry*
- *Trends in Biotechnology*
- *Trends in Microbiology*
- *Trends in Plant Sciences*

Websites

- http://testweb.science.uu.nl/pmi/
- popups.ulg.ac.be/1780-4507/index.php?id=7578
- www.researchgate.net/...The_rhizosphere_microbiome_and_plant_health...
- journal.frontiersin.org/Journal/10.3389/fpls.2013.00165/abstract

- http://www.aw-bc.com/microplace/
- http://www.personal.psu.edu/jel5/micro/index.htm
- http://microbiology.ucsc.edu/
- http://www.suite101.com/links.cfm/microbiology
- http://www.microbeworld.org/resources/links.aspx
- http://www.asm.org/
- http://www.microbiologyiworld.com/
- http://www.sciencemag.org/cgi/collection
- http://www.latrobe.edu.au/microbiology/links
- www.uwstout.edu/lib/subjects/microbi
- http://www.aemtek.com

Journal related to Microbiology

- http://www.fems-microbiology.org/website/nl/default.asp
- http://www.blackwellpublishing.com/journal
- http://www.springer.com/
- http://www.e-journals.org/microbiology/
- http://pubs.nrc-cnrc.gc.ca/
- http://www.elsevier.com/
- http://www.academicjournals.org/ajmr/
- http://www.horizonpress.com/gateway/journals.html
- http://www.scielo.br/bjm
- http://www.jmb.or.kr/
- http://microbiologybytes.wordpress.com/
- http://www.topix.net/science/microbiolog

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Plant Physiology

Preamble

The last decade witnessed phenomenal progress in science and technology resulting in the accruement of significant new scientific developments in plant sciences, more specifically on plant growth, development and productivity. This necessitates restructuring the curriculum and the syllabus to enable graduate students to be abreast with the developments through providing comprehensive exposure to the M.Sc and Ph.D. students, on new developments in different areas of plant sciences. With this background the structure of curriculum for M.Sc. and Ph.D. program and syllabi for the courses needs to be developed keeping in view the mandate of agriculture universities and crop specific ICAR institutes.

Genetic enhancement to achieve crop improvement is the major mandate of state agricultural universities (SAU) and crop specific institutes. The emphasis has systematically shifted towards improving specific physiological traits and mechanisms to enhance crop productivity, yield potentials, adaptation to stresses, etc. Yet another major mandate is to optimize agronomic inputs for yield enhancement to rationalize utilization of natural resources. As the crop improvement success heavily depends on improving physiological processes, plant/crop physiology will immensely contribute to the envisaged goals. With this background the M.Sc and Ph.D. students must be provided with adequate exposure and trainings on plant/crop physiology to complement national and state level crop improvement and crop production programs. The focus is to restructure the course content and syllabi of physiology courses to achieve these objectives. While restructuring and modifying the course curriculum it is necessary to take into cognisance the recent developments in molecular biology, genomics and phenomics which provide options to identify traits and their genetic enhancement. Besides potential interventions, the restructured courses should provide insight based on sound physiological process which now provided options to regulate the plant growth and productivity. Therefore, emphasis is on,

- Providing basic knowledge on plant physiological processes and plant responses to environment and other constraints
- Providing exposure to undertake programs for crop improvement by exploiting well characterized physiological processes
- Provides exposure on potential interventions based on principals of plant physiology to improve growth and productivity

M.Sc courses

Twelve courses for M.Sc have been developed, out of which 8 are the meticulous modification of existing courses, and rest 4 courses are newly designed with focus on applications of physiological process for crop improvement and crop productivity.
For M.Sc. Programme – emphasis is on four aspects:

I. Basic Plant Physiology Courses (PP 501, PP 502, PP 503)

These fundamental courses give exposure on basic principles of plant physiology, water relations, plant metabolic processes and on developmental biology. Also provides exposure on recent developments on plant growth and development, and aspects related to photomorphogenesis, photoperiodism, fruit ripening and senescence. Attempts were made to remove redundancy from UG programme and add new recent concepts and developments.

II. Physiology courses that provide insights on plant responses to environmental and internal factors (PP 504, PP 505, PP 506)

Plant Phenome is a reflection of genetic makeup, interaction with environment and internal factors. Therefore, basic aspects of plant responses to abiotic stresses and stress tolerance mechanisms form the basis for improving adaptation of crops to stress. Phytohormones are major internal factors and signaling molecules to regulate plant growth, differentiation and development. Mineral nutrients are essential for plant metabolic processes besides being essential constituents of many macromolecules. Emphasis is to introduce new emerging concepts and molecular mechanisms.

III. Crop physiology courses related to crop productivity (PP 507, PP 508, PP 509, PP 510)

Agronomic inputs and environmental factors enhance crop growth through optimizing photosynthesis processes and canopy photosynthesis and net carbon gain drives the crop growth rates. Further, components of growth and yield structure with environmental interaction forms the basis for crop modeling.

In recent years, phenomenal progress has been made in understanding plant processes which are crop specific. Therefore, physiological aspects of crop growth and productivity of specific field and horticultural crops needs to be discussed.

The physiological aspects that need to be discussed should focus not only to address basic growth and developmental aspects of these crops but also emphasis should be given on the major production constraints and the physiological approaches to overcome.

IV. Student ready courses – application of physiological processes for crop improvement and crop production (PP 511, PP 512)

The mandate of SAUs and crop specific institutes of ICAR is crop improvement and crop production. These "*student-ready*" courses provide exposure on quantifying relevant physiological processes and capturing genetic variability, which complement breeding programs aimed at improving specific plant traits. Further, many physiological processes can now be exploited to improve growth and productivity. Several interventions that alter the developmental growth processes can be exploited to bring in synchronization of flowering, soilless cultures, pollen biology, light regulation in polyhouses, etc. Emphasis is to complement the crop improvement and productivity approaches.

Ph.D. courses

In PhD programme, 10 courses are finalized, out of which 7 are the thorough modification of existing courses, and rest 3 courses are newly designed. From the existing syllabus, one course is shifted to MSc programme with comprehensive modification.

For Ph.D. Programme – emphasis is on five aspects:

I. Exposure to the genomic tools and genetic resources (PP 601, PP 602, PP 603)

Focus is on identifying genes regulating the specific mechanisms/traits. Objective is to provide comprehensive exposure on different approaches and technologies to assess the functions of genes regulating plant physiological processes and biochemical mechanisms. It is well documented that plant response to external and internal factors is mainly through signal perception and amplification leading gene expression which bring in altered metabolism regulating physiological and biochemical processes and finally plant processes and growth. There is need to provide sufficient information on diverse receptors, ligand-receptor interactions and the role of secondary messengers in signal amplification leading to gene expression.

Phenomenal progress in understanding the basic physiological mechanisms that determine crop performance and "physiological traits" that have enormous relevance to improve yield potentials as well as adaptation to various biotic and abiotic stresses have been enumerated, well studied and documented. Although most of the physiological traits have been considered as complex and hard to breed, recent advances in understanding the sub-components of most of the major mechanisms coupled with the progress made in "phenotyping" to capture genetic variability in such subcomponent traits, have paved way for the adoption of "trait-based breeding" approaches. Finally, assess the relevance of physiological processes/mechanisms and develop options to combine/introgress them.

II. To characterize and capture the genetic variability in plant traits and adaptive mechanisms (PP 604, PP 605)

Phenotyping plant traits is the crucial input to complement the progress made in genomics. Phenomenal progress made in genomics cannot be exploited for improving plant traits/mechanisms unless phenotyping technologies are developed to capture genetic variability. Several technologies have been developed to quantify the traits and assess genetic variability. Genetic enhancement of specific plant traits is now "Pheno-centric".

Further, techniques, tools and instrumentation facilities drive the research in modern biology. These courses address recent developments related to phenotyping and phenomics and advances made in quantification methods based on novel methodologies and instruments. Emphasis on recent concepts on high throughput phenotyping options for crop improvement.

III. Predicting climate change, causative factors, their quantification, and effect on plant growth and development (PP 606)

Main focus is prediction of climate change, mitigation options and adaptive mechanisms. Predicting climate change variability, causative factors and their quantification and finally effects on plant growth and development is the main emphasis.

IV. Comprehensive insight and options to address major constraints in crop improvement (PP 607, PP 608)

Yield level reached plateau in many crops. Improving yield potential and crop growth rate forms the basis for further improvement in productivity. Photosynthesis and the establishing sink capacity are crucial processes to achieve this goal. Comprehensive exposure is needed as progress made in deciphering the molecular mechanisms to regulate several photosynthetic processes at cellular and canopy level, and also sink development processes.

Seed as a propagule is an important input for agriculture. From this context aspects related to seed development, its dormancy and viability etc. assumes significance. Besides seed is the major source of nutrition to mankind, hence quantitative and qualitative differences in seed constituents and their modification and improvement has been the area of focus in recent years. Emphasis on new conceptual approaches to enhancing yield potential and qualitative traits of seeds and fruits.

V. Plant interaction with biotic factors (Pathogens, Insects and weeds) (PP 609, PP 610)

Besides the genetic makeup expression of the phenotype is regulated by environment and the plant microbe interaction especially the endophytes. Besides it is relevant to understand the plant pathogen and plant insect interactions to improve tolerance mechanisms by altering specific physiological and biochemical processes. Weeds are one of the major biotic factors that affects yield in agricultural crops. Besides understanding weed biology and reproductive strategies of weeds recent concepts in developing selective herbicides based on mode of action and herbicide tolerance mechanisms provided greater insights in weed management. Genome editing options to develop herbicide tolerant transgenics is an exciting option.Implemntation of the revised syllabus needs a sanction of an approximate recurring budget of ₹ 20 lacs per annum in addition to aone time equipment and maintenance grant of ₹ 2 crores.

Course Title with Credit Load
M.Sc. (Ag) in Plant Physiology

Course Code	Course Title	Credit Hours
PP 501*	Principles of Plant Physiology-I: Plant Water Relations and Mineral Nutrition	2+1
PP 502*	Principles of Plant Physiology-II: Metabolic Processes and Growth Regulation	2+1
PP 503*	Plant Developmental Biology: Physiological and Molecular Basis	2+1
PP 504	Physiological and Molecular Responses of Plants to Abiotic Stresses	2+1
PP 505	Hormonal Regulation of Plant Growth and Development	2+1
PP 506	Physiological and Molecular Mechanisms of Mineral Nutrient Acquisition and their Functions	2+1
PP 507	Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modelling	2+1
PP 508	Physiology of Field Crops	2+0
PP 509	Physiology of Horticulture Crops	2+0
PP 510*	Seed Physiology	2+1
PP 511	Phenotyping Physiological Processes	2+0
PP 512	Crop Growth Regulation and Management	2+0
PP 591	Master’s Seminar	1+0
PP 599	Master’s Research	30

Course Contents
M.Sc. (Ag) in Plant Physiology

I. Course Title : Principles of Plant Physiology I - Plant Water Relations and Mineral Nutrition

II. Course Code : PP 501*

III. Credit Hours : 2+1

IV. Why this Course?

Plant's growth and development and therefore, agricultural productivity depends on two major inputs like water and nutrients. In this regard, this course being a fundamental course will acquaint the students with the basic concepts of plant water relations and mineral nutrition. The course provides a basic knowledge on water and nutrient acquisition and their transport throughout the phenological stages. Further, it also provides hands on experience in assessing the plant and soil water status besides nutrient acquisition by plants.

V. Aim of the Course

The aim of this course is to impart knowledge in the field of water relations and mineral nutrition and how plants acquire water and transport it under different soil water regimes and also make use of the water in an effective way to maximize use efficiency. In addition, the other aim is to impart knowledge of how plants minimize water loss under stress conditions besides educating the students of how plants make use of nutrients in a best possible way.

The course is organized as follows:

No.	Blocks	Units
1.	Plant Water Relations	1. Soil and Plant Water Relations 2. Water Absorption and Translocation 3. Transpiration and Evaporative Cooling 4. Water Productivity and Water Use Efficiency 5. Moisture Stress and Plant Growth
2.	Mineral Nutrition	1. Nutrient Elements and their Importance 2. Nutrient Acquisition 3. Concept of Foliar Nutrition

VI. Theory

Block 1: Plant Water Relations

Unit 1: Soil and Plant Water Relations

Water and its importance; Molecular structure of water; Properties and functions of water. Concept of water potential; Plant cell and soil water potential and their components; Methods to determine cell and soil water potential; Concept of osmosis and diffusion. Soil physical properties and water availability in different soils;

Water holding capacity and approaches to improve WHC; Concept of FC and PWP; Water holding polymers and their relevance.

Unit 2: Water Absorption and Translocation

Root structure and functions; Root architecture and relevance in water mining; Mechanism of water absorption and translocation; Theories explaining water absorption and translocation; Aquaporins. Mycorrhizal association and its relevance in water mining.

Unit 3: Transpiration and Evaporative Cooling

Evaporation and transpiration; relevance of transpiration; factors regulating transpiration; Measurement of transpiration; approaches to minimize evaporation and transpiration; Concept of CCATD and its relevance. Energy balance: Solar energy input and output at crop canopy level. Stomata- its structure, functions and distribution; Molecular mechanisms of stomatal opening and closing; Concept of guard cell turgidity; role of K and other osmolytes; role of ABA in stomatal closure; Guard cells response to environmental signals; Signaling cascade associated with stomatal opening and closure. Antitranspirants and their relevance in agriculture.

Unit 4: Water Productivity and Water Use Efficiency

WUE and its relevance in water productivity; Transpiration efficiency, a measure of intrinsic WUE; Approaches to measure WUE; Stomatal and mesophyll regulation on WUE; Passioura's yield model emphasizing WUE.

Unit 5: Moisture Stress and Plant Growth

Physiology of water stress in plants; Effect of moisture stress at molecular, cellular, organ and plant level. Drought indices and drought tolerance strategies. Drought tolerance traits.

Block 2: Mineral Nutrition

Unit 1: Nutrient Elements and Their Importance

Role of mineral nutrients in plant's metabolism; Essential elements and their classification; Beneficial elements; factors influencing the nutrients availability; critical levels of nutrients. Functions of mineral elements in plants. Deficiency and toxicity symptoms in plants.

Unit 2: Nutrient Acquisition

Mechanism of mineral uptake and translocation; Ion transporters; genes encoding for ion transporters; localization of transporters; xylem and phloem mobility; Nutrient transport to grains at maturity; Strategies to acquire and transport minerals under deficient levels. Role of mycorrhiza, root exudates and PGPRs in plant nutrient acquisition.

Unit 3: Concept of Foliar Nutrition

Foliar nutrition; significance and factors affecting total uptake of minerals; Foliar nutrient droplet size for effective entry; role of wetting agents in entry of nutrients.

VII. Practicals

- Standard solutions and preparation of different forms of solutions
- Studies on the basic properties of water
- Demonstration of surface tension of water and other solvents
- Measurement of plant water status: Relative water content and rate of water loss

- Determination of water potential through tissue volume and Chardakov's test
- Determination of water potential using pressure bomb, osmometer, psychrometer
- Determination of soil moisture content and soil water potential
- Use of soil moisture probes and soil moisture sensors
- Measurement of transpiration rate in plants; use of porometry
- Measurement of CCATD and its relevance
- Demonstration and use of anti-transpirants to reduce transpiration
- Influence of potassium and ABA on stomatal opening and closing respectively
- Deficiency and toxicity symptoms of nutrients
- Effect of water stress on plant growth and development

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

- comprehend the fundamental concepts of plant physiological processes associated with water relation and mineral nutrition.
- describe the physiological mechanisms of water relation and mineral nutrition.
- recognize and describe how plants respond to mineral deficiency and toxicity.

X. Suggested Reading

- Vilalta JM and Forner NG. 2017. *Water potential regulation, stomatal behaviour and hydraulic transport under drought: deconstructing the iso/anisohydricconcept Plant, Cell and Environment* 40, 962–976
- Mangrich AS, Cardoso EMC, Doumer ME, Romão LPC, Vidal M, Rigol A, Novotny EH. *Improving the Water Holding Capacity of Soils of Northeast Brazil by Biochar Augmentation.* Chapter 16, pp 339–354.
- McElrone AJ, Choat B, Gambetta GA and Brodersen CR. 2013. *Water Uptake and Transport in Vascular Plants. Nature Education Knowledge* 4(5): 6
- Hodson RC and J Acuff. 2006. *Water transport in plants: anatomy and physiology*. Pages 163-183, *Tested Studies for Laboratory Teaching*, Volume 27 (M.A. O'Donnell, Editor). Proceedings of the 27th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 383 pages.
- Chater CCC, Caine RS, Fleming AJ, Gray JE. 2017. *Plant Physiology,* 174 (2) 624-638; DOI: 10.1104/pp.17.00183
- Dietrich P, Sanders D, Hedrich R. 2001. *The role of ion channels in light dependent stomatal opening, Journal of Experimental Botany*, Volume 52, Issue 363, Pages 1959–1967, https://doi.org/10.1093/jexbot/52.363.1959
- Sreeman SM, Vijayaraghavareddy P, Sreevathsa R, Rajendrareddy S, Arakesh S, Bharti P, Dharmappa P, Soolanayakanahally R. 2018. *Introgression of Physiological Traits for a Comprehensive Improvement of Drought Adaptation in Crop Plants. Front. Chem*. 6, 92.
- Seyed Yahya Salehi-Lisar Hamideh Bakhshayeshan-Agdam, (2016). Drought Stress in Plants: Causes, Consequences, and Tolerance. Drought Stress Tolerance in Plants, Vol 1 pp 1-16
- Pandey R. 2015. *Mineral Nutrition of Plants*. 10.1007/978-81-322-2286-6_20.
- Barker AV and DJ Pilbeam. 2015. Handbook of Plant Nutrition, Second Edition. Books in Soils, Plants, and the Environment Series, the 2nd Edition, CRC Press.
- Vatansever R, Ozyigit II and Filiz E. 2017. *Essential and beneficial trace elements in plants, and their transport in roots: a review. Applied biochemistry and biotechnology* 181(1), 464-482..

- Tahat MM and Sijam K. 2012. *Arbuscularmycorrhizal fungi and plant root exudates bio-communications in the rhizosphere. African Journal of Microbiology Research*, 6(46), 7295-7301.
- Rajasekar MD, Nandhini DU and Suganthi S. 2017. *Supplementation of Mineral Nutrients through Foliar Spray – A Review. Int.J.Curr.Microbiol.App.Sci.* 6(3): 2504-2513.https://doi.org/10.20546/ijcmas.2017.603.283
- Tarek A and Hassan ER. 2017. *Foliar application: from plant nutrition to biofortification.* Environment, Biodiversity and Soil Security. 10.21608/jenvbs.2017.1089.1006.

General Source of Information

- Taiz T, Zeiger E and Max Mller IM, 2018, *Fundamentals of Plant Physiology*
- Taiz L and Zeiger E. 2015. *Plant Physiology and development*.6th Ed
- Salisbury FB and Ross C. 1992 (4th Ed.) *Plant Physiology*
- Epstein E and Bloom AJ. 2004. *Mineral nutrition of plants: principles and perspectives*.2nd Ed.
- Hopkins WG and Huner NPA. 2004. *Introduction to Plant Physiology*
- Kramer, P. J., *Water relations of plants*
- Kirkham, M. B., *Principles of soil and plant water relations*
- Hopkins WG, 2008, *Introduction to Plant Physiology*

I. Course Title : Principles of Plant Physiology-II: Metabolic Processes and Growth Regulation

II. Course Code : PP 502*

III. Credit Hours : 2+1

IV. Why this course?

Mechanisms associated with growth and development determine crop performance under any given condition. Metabolic and growth processes are quite sensitive to environmental factors and hence comprehensive understanding of the physiological basis of growth and development would be essential.

V. Aim of the course

This course will impart knowledge on cellular structure and function that determine of carbon and nitrogen metabolism, lipids, enzymes and secondary metabolites in plants. Relevance of metabolic processes on growth and development leading to productivity will be dealt.

The course is organized as follows:

No.	Blocks	Units
1.	Metabolic processes and growth regulation	1. Carbon Metabolism–Photochemical Processes 2. Carbon Metabolism: Biochemical Processes 3. Carbon Metabolism: Respiration 4. Product Synthesis and Translocation Leading to Crop Growth 5. Nitrogen Assimilation and Protein Synthesis 6. Lipid Metabolism and Secondary Metabolites 7. Hormonal Regulation of Plant Growth and Development 8. Synthetic Growth Promoters 9. Morphogenesis and Reproductive Phase

VI. Theory

Block 1: Metabolic Processes and Growth Regulation

Unit 1: Carbon Metabolism – Photochemical Processes

- Chloroplast ultrastructure with special mention of lamellar system
- Excitation, electron and proton transfers and their relevance in energy conservation
- Concepts of pigment systems and generation of powerful reductant and oxidant
- Water oxidation, Water-water cycle and other aspects of electron transfer

Unit 2: Carbon Metabolism: Biochemical Processes

- CO_2 diffusion mechanisms and diffusive conductances, concept of Ci determining Photosynthesis
- RuBisCO enzyme kinetics and Calvin cycle mechanisms, Regulation of Calvin cycle and metabolite fluxes
- Photorespiration: the advantages and inefficiencies of photosynthesis because of photorespiration
- Concepts of CO_2 concentrating mechanisms (CCM) and spatial and temporal differences in carboxylation
- Ecological aspects of $C_4$and CAM photosynthesis
- Product synthesis, Starch and Sucrose biosynthesis

Unit 3: Carbon Metabolism: Respiration

- Mitochondrial organization and functions
- Aspects of Glycolysis, TCA cycle and mitETC.
- Relevance of growth and maintenance respiration
- Concepts of CN resistance respiration – Alternate and SHAM sensitive ETC

Unit 4: Product Synthesis and Translocation Leading to Crop Growth

- Phloem loading and sugar transporting, concepts of bi-directional transport of sugars and other metabolites
- Source-Sink relationship and modulation of photosynthesis
- Concepts and definitions of Growth and Differentiation
- Growth and yield parameters, NAR, CGR, HI and concepts of LAI, LAD

Unit 5: Nitrogen Assimilation and Protein Synthesis

- Developments in d-nitrgen fixation
- Nitrate reduction and assimilation GS-GOGAT process for amino acid synthesis
- Inter-Dependence of carbon assimilation and nitrogen metabolisms

Unit 6: Lipid Metabolism and Secondary Metabolites

- Storage, protective and structural lipids.
- Biosynthesis of fatty-acids, diacyl and triacyl glycerol, fatty acids of storage lipids.
- Secondary metabolites and their significance in plant defense mechanisms.

Unit 7: Hormonal Regulation of Plant Growth and Development

- Growth promoting and retarding hormones: biosynthesis, transport, conjugation
- Mode of action of these hormones and their application in plant physiology

Unit 8: Synthetic Growth Promoters

- Different synthetic hormones: Salicylic acid, strigolactones etc
- Roles and biological activities of various synthetic hormones
- Commercial application of hormones to maximize growth and productivity

Unit 9: Morphogenesis and Reproductive Phase

- Photoperiodism: Phytochromes, their structure and function
- Circadian rhythms,
- Blue light receptors: Cryptochrome and morphogenesis.
- Vernalization and its relevance in germination.

VII. Practicals

- Radiant energy measurements
- Separation and quantification of chlorophylls
- Separation and quantification of carotenoids
- O_2 evolution during photosynthesis
- Anatomical identification of C_3 and C_4 plants
- Measurement of gas exchange parameters, conductance, photosynthetic rate, photorespiration
- Measurement of respiration rates
- Estimation of reducing sugars, starch
- Estimation of NO_3, free amino acids in the xylem exudates, quantification of soluble proteins
- Bioassays for different growth hormones- Auxins, Gibberellins, Cytokinins, ABA and ethylene
- Demonstration of photoperiodic response of plants in terms of flowering

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

- figure out the fundamental metabolic processes in plant
- describe the physiological mechanisms and metabolic events associated with regulation of plant growth

X. Suggested Reading

- Kirchhoff H. 2019. *Chloroplast ultrastructure in plants*, New Phytologist. Doi.org/10.1111/nph.15730
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- Li, C., Li, J., Chong, K., Harter, K., Lee, Y., Leung, J.,and Schroeder, J. 2016. *Toward a molecular understanding of plant hormone actions*. *Molecular plant*, 9(1), 1-3.
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- Jiang, K., andAsami, T. 2018. *Chemical regulators of plant hormones and their applications in basic research and agriculture*. *Bioscience, biotechnology, and biochemistry*, 82(8), 1265-1300.
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General Text books

- *Taiz, Lincoln, Zeiger. 2007 Plant Physiology, Eduardo Original American edition Sinauer Associates, Inc., 2006; 4th ed., XXVI, ISBN: 978-3-8274-1865-4; © Springer.*
- *Plant Physiology* Frank Boyer Salisbury and Cleon Ross.
- *Introduction to Plant Physiology* (Wie)by William G. Hopkins.

I. Course Title : Plant Developmental Biology: Physiological and Molecular Basis

II. Course Code : PP 503*

III. Credit Hours : 2+1

IV. Why this Course?

From the conventional description information on plant growth and development based on morphology and anatomy, phenomenal changes and leads taken place in the last one and half decade to address these processes at physiological, biochemical and molecular levels. This basic understanding has provided options to regulate these processes genetically using genetic and molecular tools and by interventions using chemicals and external factors. To give an example on flowering, the progress made regarding the molecular players that regulate flowering, initiation, the photoreceptors like phytochromes and their regulation by the photoperiod-short and long days has provided options to manipulate the flowering time to bring in synchrony, etc. Phenomenal progress also made in several other processes like germination, viability, root development and pollination, etc. The other major area of contribution is in tissue culture where is understanding of plant developmental biology has been put o practical use and knowledge on morphogenesis is exploited to maximum. It is very essential that the students get exposed on these aspects to complement the research programs on crop improvement.

V. Aim of the course

To explain about basic physiological and molecular processes concerning various facets of growth and development of plants. It provides knowledge on basic physiological processes governing developmental events in plants including senescence and fruit development and ripening. Development of vegetative tissue like shoot, leaf and root and morphogenetic phenomena like flower induction and development, factors associated with photoperiod and thermoperiod response. Regulation of morphogenesis would be studied at the molecular level providing information on genes involved. In addition, students will study how to apply the knowledge on plant development and morphogenesis using tissue culture.

The course is organized as follows:

No.	Blocks	Units
1.	Plant Developmental Biology	1. Evolutionary Development of Plants and Role of Environment 2. Physiological and Molecular Determinants of Seed Biology 3. Vegetative Growth and Organ Development 4. Physiological and Molecular Aspects of Reproductive Growth and Development 5. Ripening and Senescence 6. Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature
2.	Practical application of morphogenesis	1. Tissue culture and micro-propagation 2. Application of in-vitro techniques for crop improvement

VI. Theory

Block 1: Plant Developmental Biology

Unit 1: Evolutionary Development of Plants and Role of Environment

Plant development and plasticity, evolution, Biodiversity. Novel features of plant growth and development, Concept of plasticity-evolution and biodiversity, Model plants for study; Environment and development. Developmental stages and program; Cell-cycle, totipotency and regeneration.

Unit 2: Physiological and Molecular Determinants of Seed Biology

Seed development- Physiology of seed development, role of hormones in embryo development; seed development and maturation. Seed dormancy- Physiological and molecular mechanism of seed dormancy regulation. Seed germination- seed structure and Hormonal regulation of germination, Mobilization of food reserves during seed germination.

Unit 3: Vegetative Growth and Organ Development

Regeneration and totipotency- organ differentiation and development – role of hormones- developmental control genes in crop plants. Meristems in plant development. Shoot, Leaf, Trichome and stomate development and differentiation. Axillary shoot branching; Bud dormancy and growth. Root development; Nodule development; Tuber development- hormonal control, signaling and molecular regulation- genes involved. Vascular bundle development- xylem and phloem differentiation

Unit 4: Physiological and Molecular Aspects of Reproductive Growth and Development

Floral Induction and Development: Molecular and physiological mechanism of transition -vegetative to reproductive phase- floral organ initiation and development their controls. Development of male and female gametophyte; gametophytic mutants: pollen-stigma interaction- Pollen germination and tube growth; role of imprinting; Male sterility: and fertility restoration; Self incompatibility; Sterility and fertility restoration, Maternal gene effects, Zygotic gene effects. Sex determination in plants, mate choice in plants. Embryo and endosperm development- fertilization, role of imprinting; Parthenocarpy and apomixes

Unit 5: Ripening and Senescence

Fruit development, enlargement, maturation and ripening; climacteric and non-climacteric fruit ripening mechanism. Hormonal, biochemical & Molecular aspects of fruit ripening. Senescence and its regulation; Hormonal and environmental control of senescence; PCD in the life cycle of plants.

Unit 6: Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature

Light control of plant development: Phytochromes and cryptochromes, phototropins, their structure, biochemical properties and cellular distribution. Molecular mechanisms of light perception, signal transduction and gene regulation. Photoperiodism and its significance, vernalization and hormonal control. Circadian rhythms-biological clocks and their genetic and molecular determinants. Thermomorphogenesis- Thermoperiodism

Block 2: Application of Morphogenesis and its Practical Application

Unit 1: Tissue culture and micro-propagation

Applications of tissue culture for plant production, callus induction, somatic embryogenesis, regeneration from different explants. Micro-propogation, tip and axillary node culture of commercially important crops, hardening and ex-vitro establishment, concept of somatic hybridization and protoplast culture.

Unit 2: Application of *in-vitro* techniques for crop improvement

Development of somoclones, identification and exploitation of somoclonal variants.

Haploid production, pollen/anther, ovule/ovary culture. Production of secondary metabolites by tissue culture, concept of bio-fermenters. Plant transformation, development of transgenic plants and their characterization. Germplasm storage, cryopreservation and regulation

VII. Practicals

- Studying shoot apical meristem, floral meristem development and pollen tube development
- Phenotyping photomorphogenesis: (a) Studying effect of day length (short day and long day) in regulating floral induction/ flowering time in short day/long day/day neutral plants and (b) effect of light on seed germination in light-sensitive and -insensitive seeds.
- Studying effect of temperature on– (a) thermomorphogenesis- measuring hypocotyl elongation under different temperature conditions and (b) sex determination using cucurbits/sesame plants.
- Measure physiological paramters of fruit ripening and study the expression of key genes regulating ripening.
- Study the effect of ethylene, its inhhibitor and scruber on ripening (tomato).
- Study different sterilization techniques, prepare media stocks and plant hormones.
- Inoculate explant (seed and leaf tissue) of model plant for callus induction.
- Subculture the callus and standerdize regeneration protocol for shoot and root induction using callus and leaf explant.
- Micro-propagation using meristem tip and axillary node culture.
- Standerdize anther/ pollen culture for haploid production in model/crop/horticultural plant.
- Isolation of protoplast from Arabidopsis/tobacco and its culturing
- Study about selectable marker, reporter gene, PCR, southern and northern blotting techniques.
- Transformation of tobacco callus or leaf explant by *Agrobacterium tumefacines* and *Agrobacterium rhizogenes* for production of transgenic
- Molecular characterization of transgenic- PCR, southern blotting, gene expression.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular basis of plant growth and development. The student will develop critical insight in physiological aspects of vegetative growth and reproductive development at molecular level.

X. Suggested Reading

- Niklas KJ. *Plant Evolution- An Introduction to the History of Life.*
- Bahadur *B et al.* (eds.), *Plant Biology and Biotechnology:* Volume I: Plant Diversity, Organization, Function and Improvement
- Jong MD and Leyser O. *Developmental Plasticity in Plants*. Cold Spring Harbor Symposia on Quantitative Biology. 63-73.
- Inze D and Veylder LD. 2006. *Cell Cycle Regulation in Plant Development*. Annu. Rev. Genet. 2006. 40: 77–105

- J. Derek Bewley *et al*., Seeds-Physiology of Development, Germination and Dormancy.
- Kent J. Bradford and Hiroyuki Nonogaki (2007). *Seed Development, Dormancy and Germination*. Blackwell publishing.
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- Pua EC and Davey MR. *Plant Developmental Biology - Biotechnological Perspectives*.
- Meng Chen. 2004. *Light Signal Transduction In Higher Plants Annu. Rev. Genet*. 38: 87–117.
- Fankhauser C and Chory J. 1997. *Light Control Of Plant Development Annu. Rev. Cell Dev. Biol*. 13: 203–229.
- Mieke de Wit. 2016. *Light-Mediated Hormonal Regulation of Plant Growth and Development. Annu. Rev. Plant Biol*. 67: 22.1–22.25
- Franklin KA and Wigge PA. *Temperature and Plant Development*. Wiley Blackwell.
- Franklin KA *et al*. 2014. *Interaction of light and temperature signaling. Journal of Experimental Botany*. 65(11): 2859–2871.
- Bhojwani SS and Razdan MK. *Plant tissue culture: theory and practice, a revised edition*. Elsiver publication.
- Bhojwani SS, Dantu SS and Kumar P. *Plant Tissue Culture: An Introductory Text*.
- George EF and Hall MA. *Plant Propagation by Tissue Culture* 3rd Edition.
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General Source Information

- Eng-Chong Pua and Michael R.Davey: *Plant Developmental Biology - Biotechnological Perspectives*.
- B. Bahadur *et al*. (eds.), *Plant Biology and Biotechnology*: Volume I: Plant Diversity, Organization, Function and Improvement.
- Bewley JD *et al*., *Seeds-Physiology of Development, Germination and Dormancy*.
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I. Course Title : Physiological and Molecular Responses of Plants to Abiotic Stresses

II. Course Code : PP 504

III. Credit Hours : 2+1

IV. Why this course?

With the changing climate, plants are being more frequently exposed to abiotic stresses like, water, salinity, temperature, nutrient, radiation, etc. limiting the productivity. This will not only affect livelihoods of individual farmers but also the food security. Concerted efforts have been made to grow crops under resource limited/stressful environmental conditions and advances in physiology, molecular biology and genetics have significantly helped in this endeavor. In recent years, our understanding of the physio-morphological, biochemical and molecular adaptation of plants to resource limited/stressful environment is phenomenal. This course will outline different abiotic stresses, their impacts on agricultural productivity, stress tolerance mechanisms, stress mitigation strategies, crop improvement approaches and traits for stress tolerance.

V. Aim of the course

This course aims to describe students the abiotic-stress physiology and their effects on plant growth and productivity. This will also help students gain insights into latest developments in stress physiology and stress tolerance mechanisms, approaches for crop improvement under stressful environment.

The course is organized as follows:

No.	Blocks	Units
1.	Abiotic Stresses	1. Introduction to Abiotic Stresses
2.	Drought Stress	1. Moisture Stress Responses in Plants 2. Stress Perception and Molecular Responses of Plants to Drought Stress 3. Plant Adaptive Mechanisms to Drought 4. Approaches to Improve Drought Tolerance
3.	Salt, Heavy Metal, Water Logging, Temperature and Light Stress	1. Salt Stress 2. Heavy Metal Stress and Water Logging 3. Temperature and Light Stress

VI. Theory

Block 1: Abiotic Stresses

Unit 1: Introduction to Abiotic Stresses

Abiotic stresses major constraints to realize potential yields of crop plants, yield losses. Drought prone areas in India- Frequency of occurrence of drought, Rainfed-kharif, Rabi, Areas affected by salinity, heavy metals, water logging, high temperature scenario due to global warming.

Block 2: Drought Stress

Unit 1: Moisture Stress Responses in Plants

Drought-characteristic features; water potential in the soil-plant-air continuum. Physiological and biochemical processes affected by drought.Oxidative stress-generation of ROS and other cytotoxic compounds, their effect on cellular process. Effect on total carbon gain- decrease in photosynthetic area and function, protein turn over and lipid characters, phenology-reproductive aspects, critical stages.

Unit 2: Stress Perception and Molecular Responses of Plants to Drought Stress

Stress perception andsignal transduction leading to expression of regulatory genes, stress specific kinases, stress specific transcription factors, functional genes associated with adaptive mechanisms.

Unit 3: Plant Adaptive Mechanisms to Drought

(a) Escape and desiccation avoidance mechanism

Concept of stress escape- exploiting genetic variability in phenology, Drought avoidance mechanisms- Maintenance of cell turgor, water mining by root characters. Moisture conservation- Regulation of transpiration- traits reducing heat load, Stomatalfactors guard cell metabolism, moisture conservation by waxes. Water use efficiency (WUE) and concept of water productivity- regulation of transpiration efficiency-stomatal conductance, mesophyll efficiency, relevance of WUE and Passioura's model.

(b) Desiccation tolerance- Concept of acquired tolerance

Decreased turgor mediated upregulation of cellular tolerance mechanisms, Osmolytes, managing cytotoxic compounds, ROS, RCC, scavenging - enzymatic and non-enzymatic, protein turnover, stability, chaperones, membrane stability, photo-protection of chlorophylls.

Unit 4: Approaches to Improve Drought Tolerance

Development of genetic resources- donor genotypes for specific traits, Genomic resources- genes, QTL's regulating adaptive mechanisms, Conventional, transgenic and molecular breeding approaches to improve relevant adaptive traits, concept of trait introgression.

Block 3: Salt, Heavy Metal, Water Logging, Temperature and Light Stress

Unit 1: Salt Stress

Soil salinity-Effect of salt stress, ionic and osmotic effects; species variation in salt tolerance; glycophytes and halophytes, Salt tolerance mechanisms - exclusion, extrusion and compartmentalization, Signaling during salt stress – SOS pathway, Approaches to improve salt tolerance.

Unit 2: Heavy Metal Stress and Water Logging

Heavy metal toxicity in plants (eg., Al, Cd), tolerance mechanisms and approaches to improve. Plant response to water logging, role of hormones- ethylene, mechanism of tolerance and approaches to improve.

Unit 3: Temperature and Light Stress

High and low temperatures; effect on plants; adaptive mechanisms, evaporation cooling, concept of cellular tolerance, protein stability, chaperones, HSPs, HSFs, membranes. High light and high ionizing radiation- photo oxidation and photo-inhibition; mechanisms of tolerance, plant adaptation to low light, concept of shade avoidance response (SAR).

VII. Practicals

- Measurement of soil and plant water status.
- Drought stress imposition and measurement of physiological and biochemical changes in plants under stress –gas exchange and fluorescence measurements.
- Determination of water use efficiency as a drought resistant trait.
- Drought Susceptibility Index (DSI) -precise field technique to identify productive genotypes under stress.
- Approaches to quantify root characters
- Determination of stomatal parameters and canopy temperature as a reflection of transpiration and root activity.
- Determination of Salinity Tolerance Index.
- Studying acclimation response - Temperature induction response.

- Heat tolerance and membrane integrity- Sullivans heat tolerance test.
- Quantification of osmolytes – proline under stress.
- Oxidative stress imposition- Quantification of oxidative stress
- Quantification of ROS under stress.
- Estimation of ABA content in leaf and root tissues under stress.
- Determination of Sodium and Potassium in plant tissue grown under salt stress.
- Estimation of antioxidant enzymes.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular responses of plants to abiotic stresses. The student will develop critical insight in adaptive mechanisms of plants against various abiotic stresses.

X. Suggested Reading

- *Plant Physiology Book by Eduardo Zeiger and Lincoln Taiz.*
- Plant Physiology Book by Frank B. Salisbury, Cleon W. Ross Salisbury, Frank B
- Pereira A. 2016. *Plant Abiotic Stress Challenges from the Changing Environment. Front. Plant Sci*. 7: 1123. doi: 10.3389/fpls.2016.01123
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I. Course Title : Hormonal Regulation of Plant Growth and Development

II. Course Code : PP 505

III. Credit Hours : 2+1

IV. Why this Course?

Many plant growth and developmental processes are regulated by phytohormones.

It is important to understand the hormone biosynthesis, structure, function, signal transduction and their practical application. It is also important to provide basic knowledge on manipulating growth and developmental processes using plant hormones.

V. Aim of the course

It provides knowledge on the fundamentals of hormone biosynthesis, homeostasis, transport and signaling and the role in regulating basic physiological processes governing developmental events in plants.The role of classical hormones on developmental processes from germination, shoot and root apical meristem differentiation, flowering, seed maturation and senescence. The aim of this course is to appraise the students about structure and function of plant growth regulators. The course is organized as follows:

No.	Blocks	Units
1.	Plant Growth and Development: Hormonal Regulation	1. Introduction to Plant Hormones 2. Plant Hormones - Discovery and Metabolism 3. Physiological Role of Hormones in Plant Growth and Development 4. Endogenous Growth Substances other than Hormones 5. Hormone Signaling 6. Key Genes Regulating Hormone Levels and Functions 7. Crosstalk of Hormones in Regulation of Plant Growth and Development Processes 8. Practical Utility of Growth Regulators in Agriculture and Horticulture

VI. Theory

Block 1: Plant Growth and Development: Hormonal Regulation

Unit 1: Introduction to Plant Hormones

Growth, differentiation and development regulated by plant growth substances, Definition and classification of growth regulating substances: Classical hormones, Definition and classification of growth regulating substances: Endogenous growth substances other than hormones, Synthetic chemicals.

Unit 2: Plant Hormones – Discovery and Metabolism

Discovery, biosynthetic pathways and metabolism of Auxin, Discovery, biosynthetic pathways and metabolism of Gibberellins, Discovery, biosynthetic pathways and metabolism of Cytokinins, Discovery, biosynthetic pathways and metabolism of Abscisic acid, Discovery, biosynthetic pathways and metabolism of Ethylene, Discovery, biosynthetic pathways and metabolism of Brassinosteroids, Discovery, biosynthetic pathways and metabolism of Strigolactones.

Unit 3: Physiological Role of Hormones in Plant Growth and Development

Physiological functions of Auxin and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Gibberellins and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Cytokinins and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Abscisic acid and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Ethylene and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Brassinosteroidsand Strigolactones and use of mutants and transgenic plants in elucidating the physiological functions, Discovery, biosynthetic pathways metabolism and physiological roles of Salicylic acid and Peptide hormones.

Unit 4: Endogenous Growth Substances other than Hormones

Discovery, biosynthetic pathways metabolism and physiological role of Polyamines and Karrikins, Discovery, biosynthetic pathways metabolism and physiological roles of Jasmonates and Tricontanol, Discovery, biosynthetic pathways metabolism and physiological roles of systemins Concept of death hormone, Recent developments in elucidating responses of Salicylic acid, Peptide hormones and Polyamines at physiological and molecular level, Recent developments in elucidating responses of Jasmonates, Systemins, Karrikins and Tricontanol at physiological and molecular level.

Unit 5: Hormone Signaling

Hormone signal perception, transduction - Receptors, components and mechanism (Auxin, Gibberellin, Cytokinin, ABA and Salicylic acid), Hormone signal perception, transduction - Receptors, components and mechanism (Ethylene, Jasmonate, Brassinosteroids and strigolactones), Advances in elucidating the structure and function of receptors and signaling components of important hormones.

Unit 6: Key Genes Regulating Hormone Levels and Functions

Genomics approaches to regulate hormone metabolism and its effect on plant growth and development – case studies.

Unit 7: Crosstalk of Hormones in Regulation of Plant Growth and Development Processes

Crosstalk of Hormones in Regulation of Plant Growth and Development Processes: Floral transition, reproductive development, Shoot and root apical meristem development

Unit 8: Practical Utility of Growth Regulators in Agriculture and Horticulture

Practical Utility of Growth Regulators in Agriculture and Horticulture: Rooting of cuttings, Vine and brewing industry, Promotion of gynoecious flowers, hybrid rice production, induction of flowering in pine apple, cucurbits, Practical Utility of Growth Regulators in Agriculture and Horticulture: Delaying of senescence and ripening, Production of dwarf plants for ornamental purpose, As herbicides, Reduction in flower and fruit drop.

VII. Practicals

- Extraction of Auxins from plant tissue
- Separation and detection of Auxins by GC / GC-MS / HPLC / Immunological technique
- Bioassay of auxin- effect on rooting of cuttings
- Extraction of abscisic acid (ABA) from plant tissue
- Separation and detection of ABA by HPLC/Immunological technique
- ABA bioassays- effect on stomatal movement

- Preparation of samples for ethylene estimation in plant tissue
- Estimation of ethylene in plant tissues using gas chromatography
- Ethylene bioassays, estimation using physico-chemical techniques- effect on breaking dormancy in sunflower and groundnut
- Extraction of Gibberellins from plant tissue- GC / GC-MS / HPLC
- Separation and detection of GA by GC / GC-MS / HPLC/Immunological technique
- GA bioassays- effect on germination of dormant seeds
- Cytokinin- extraction from plant tissue
- Separation and detection of cytokinin by GC / GC-MS / HPLC
- Cytokinin bioassays- effect on apical dominance and senescence / stay green

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– acquire basic knowledge about plant hormones and plant growth regulators.
– understand the physiological roles and mechanisms of actions of plant hormone.
– obtain practical knowledge about application of plant growth regulators in agricultural and horticulture.

X. Suggested Reading

- Davies P.J. 2004, *Plant Hormones: Biosynthesis, Signal Transduction and Action,* 2nd Edition. Kluwer Academic Publishers, Dordrecht, The Netherlands.
- Hedden, P. and Thomas, S.J. 2006. *Plant Hormone Signalling*, Blackwell Publishing Ltd., Oxford, UK.
- Osborne, D.J. and McManus, M.T. 2005. *Hormones, Signals and Target Cells in Plant Development*. Cambridge University Press, New York, USA.
- Tucker, G.A. and Roberts, J.A. 2000. *Plant Hormone Protocols.* Humana Press-Springer Science, New York, USA.
- Buchanan B B, Gruissem W and Jones R L. *Biochemistry and Molecular biology of Plants*, 2nd Edition
- Lincoln Taiz and Eduardo Zeiger. *Plant Physiology and Development*, 6th Edition.
- *Teaching Tools in Plant Biology*, The American Society of Plant Biologists
- *The Arabidopsis* Book(http://www.arabidopsisbook.org/)

I. Course Title : Physiological and Molecular Mechanisms of Mineral Nutrient Acquisition and their Functions

II. Course Code : PP 506

III. Credit Hours : 2+1

IV. Why this course?

In both basic and applied plant sciences, an understanding of the mineral nutrition of plants is of fundamental importance. Nutrient element forms the skeleton of any organic molecule in the organism vis-à-vis plant. Apart from the conventional information on criteria of essentiality, nutrient uptake pathways, function of essential elements and their deficiency and toxicity symptoms, remarkable advances have been made at physiological and molecular level. Exploration of the physiological mechanisms adopted by plants to tolerate the deficiency of specific nutrient element provides an opportunity alter the plants' ability to cope with the low nutrient condition. Identification and functional validation of various transporters involved in nutrient uptake and distribution, deciphering the sensing and signaling of nutrient starvation response and their regulatory network provides options to develop nutrient uptake and utilization efficient crops. In the era of Omics, 'ionomics' provides the total elemental composition of the plant and is a powerful approach to the functional analysis of its genes and the gene networks. Besides, it is also essential to expose the students to various conventional and high-throughput phenotyping techniques to identify the nutrient efficient 'donors', traits and QTLs/ candidate genes to complement the research program on crop improvement.

V. Aim of the course

It provides knowledge on basic physiological processes governing nutrient uptake, physiological role of elements, factors influencing uptake, internal remobilization of nutrient element during starvation and adaptation strategies. Regulation of nutrient uptake and translocation would be studied at the molecular level providing information on genes and other signaling factors involved. The aim of this course is to make the students understand the physiological and molecular basis of nutrient uptake, translocation and utilization and to apply this knowledge in genetic improvement of crop plants.

The course is organized as follows:

No.	Blocks	Units
1.	Mineral Nutrient: Classification, Function, Availability, Deficiency and Toxicity	1. Mineral Elements: Classification, Function, Deficiency and Toxicity 2. Nutrient Availability at Rhizosphere
2.	Nutrient Uptake, Translocation and Acquisition	1. Ion Uptake Mechanisms 2. Ion Transport to Shoot and Grains 3. Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Macronutrients 4. Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Micro and Beneficial Nutrients 5. Microbes, Fungal Association for Nutrient Acquisition 6. Nutrient Delivery
3.	Nutrient Efficiency of Crop	1. Improving Nutrient Acquisition and Efficiency of Crops

VI. Theory

Block 1: Mineral Nutrient: Classification, Function, Availability, Deficiency and Toxicity

Unit 1: Mineral Elements: Classification, Function, Deficiency and Toxicity

Classification based on mobility and characteristic features; physiological role in regulating plant growth, metabolism, development and human health- Regulatory Dietary Allowance (RDA), Deficiency and toxicity of macro, micro and beneficial elements, Tolerance of plants to nutrient toxicity, hyper-accumulators of nutrients: Concept of phytoremediation.

Unit 2: Nutrient Availability at Rhizosphere

Biological and chemical reactions influencing nutrient availability near the root system, interaction between ions in the rhizosphere, Rhizosphere chemistry in relation to plant nutrition- chemical reactions, root exudates to mobilize nutrients.

Block 2: Nutrient Uptake, Translocation and Acquisition

Unit 1: Ion Uptake Mechanisms

Mineral salt absorption- chemical potential of solute- Nernst equation- passive uptake- diffusion, ion exchange-Donnan Equilibrium, mass flow of ions, Mediated transport- Facilitated diffusion-ionophores; membrane transport proteins- active transport-ion channels, Primary and secondary transport- carriers and pumps.

Unit 2: Ion Transport to Shoot and Grains

Long distance transport in plants - Mechanism of xylem and phloem transport, Radial movement of ions across the root, Mechanism of phloem transport, remobilization of mineral nutrients - phloem loading, phloem unloading.

Unit 3: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Macronutrients

Molecular structures of LAT and HAT, their localization and regulation by various external factors, Nitrate transporters and their functional regulation - Nitrate transporters (NRT1, NRT2, dual-affinity nitrate transporter NRT1.1/CHL1), Phosphate transporters and their functional regulation - PT1/PHT1, PHT2, PHT3, PHT4, Potassium transporters and their functional regulation - KT/HAK/KUP family Ion transporters involved in transport of multiple elements, for example, sulphate transporter for Selenate transport, phosphate transporter for Arsenate transport, etc.

Unit 4: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Micro and Beneficial Nutrients

Plant Strategies: Different Strategies I & II adopted by plants for uptake of Fe under Fe deficient condition, Transporters and genes regulating uptake and transport of micronutrients, genes encoding transport/channel proteins, Examples of genes encoding mineral ion transporters for Zn, Fe, Mn, Cu, B, Mo, Ni, Cl, Na, Si, Se, Beneficial nutrients and their role in plant growth and development – Sodium, Silicon, and Cobalt.

Unit 5: Microbes, Fungal Association for Nutrient Acquisition

Microbes to improve nutrient availability – Bio-inoculation technology- P solubilizers and Zinc solubilizers in nutrient absorption, Microbial systems for biological nitrogen fixation – process of nodulation, biochemistry of N2-fixation, Endophytes to improve nutrient availability, Mycorrhiza- Mycorrhizal symbiosis on nutrient uptake by root. Role of AMF on nitrogen, phosphorus and zinc uptake.

Unit 6: Nutrient Delivery

Foliar application of nutrients, absorption and their compartmentation, Concept of slow release fertilizers and chelates (organic and inorganic), Soil less cultures- aeroponics, hydroponics, fertigation.

Block 3: Nutrient Efficiency of Crop

Unit 1: Improving Nutrient Acquisition and Efficiency of Crops

Concept of nutrient uptake and use efficiency- Genotypic differences- physiology and molecular mechanisms, Nutrient use efficiency in selected crops, Root system architecture (RSA), root characters associated with nutrient acquisition, Genes and QTLs to improve nutrient acquisition and efficiency for important nutrients in few crop species, Transgenic and molecular breeding approaches to improve traits associated with acquisition and efficiency – Case studies, Biofortification strategies – for micronutrients, agronomic approaches, Influence of nutrition status on plant response to biotic and abiotic stresses.

VII. Practicals

- Techniques to develop the deficiency symptoms of nutrients –Hydroponics/ Aeroponics- diagnosis of deficiency symptoms in agriculturally important crop plants
- Physiological and biochemical markers to identify nutrient deficiency levels
- Biochemical markers for essential elements: Assay of nitrate reductase activity for N
- Estimation of chlorophyll concentration in leaves of N deficient and N sufficient plants
- Collection of acid phosphatase from root exudates and enzyme assay for P
- Measuring anthocyanin and chlorophyll pigments concentration in leaves for P
- Collection of organic acid in root exudates, characterization and quantification for P
- Assay of carbonic anhydrase activity for Zn
- Assay of SOD Activity for Cu, Zn and Mn
- Estimation of nitrogen concentration in plant tissue - Kjeldhal and Dumas method
- Estimation of phosphorus concentration in plant tissue – colorimetric method
- Estimation of potassium, magnesium and sodium concentration in plant tissue – flame photometer
- Estimation of micronutrients (Zn, Cu, Fe, Mn, Co etc) concentration in plant tissue – atomic absorption spectrometer/ ICP-OES
- Measurement of simple root traits such as root length, angle, volume, surface area, etc. (using conventional methods or root scanner and WinRhizo)
- 'Shovelomics' in the field grown crops (for measuring root architecture) and using 'ImageJ' for analysis
- Non-invasive techniques to quantify nutrients – XRF (X-Ray Fluorescence) and hyper spectral reflectance.

VIII. Teaching methods/ activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

– comprehend the fundamental concepts of mineral nutrition of plant.
– describe the physiological and molecular mechanisms of acquisition and translocation of nutrient.
– describe the basis of differential nutrient efficiency.

X. Suggested Reading

- *Recommended Dietary Allowances*: 10th Edition (https://www.ncbi.nlm.nih.gov/books/NBK234932/pdf/Bookshelf_NBK234932.pdf)
- da Silva Lobato, A.K., Lima, E.J.A., Lobato, E.M.S.G., Maciel, G.M. and Marques, D.J., 2016. *Tolerance of Plants to Toxicity Induced by Micronutrients. In Abiotic and Biotic Stress in Plants-Recent Advances and Future Perspectives*. IntechOpen.
- Renwick, A.G., 2006. *Toxicology of micronutrients: adverse effects and uncertainty. The Journal of nutrition,* 136(2), 493S-501S.
- Krämer, U., 2018. *The Plants that Suck Up Metal. German Research*, 40(3), 18-23.
- Surriya O, Saleem SS, Waqar, K. and Kazi, A.G., 2015. *Phytoremediation of soils: prospects and challenges. Soil remediation and Plants: Prospects and challenges*, p.1.
- Sarma, H., 2011. *Metal hyperaccumulation in plants: a review focusing on phytoremediation technology. Journal of Environmental Science and Technology*, 4(2), pp.118-138.
- Marschner H. *Mineral Nutrition of Higher Plants* 3rdEdn
- Zeiger and Taiz L. *Plant Physiology*
- *Mineral Nutrition of Plants*, *In: Plant Biology and Biotechnology*. B. Bahadur *et al*. (eds.), Volume I: *Plant Diversity, Organization, Function and Improvement*, DOI: 10.1007/978-81-322-2286-6_20, Springer India, Pp. 499-538.
- López-Arredondo DL, Leyva-González,MA, Alatorre-Cobos F and Herrera-Estrella L. 2013. *Biotechnology of nutrient uptake and assimilation in plants. International Journal of Developmental Biology*, 57(6-7-8), pp.595-610.
- Sugita, R., Kobayashi, N.I., Hirose, A., Tanoi, K. and Nakanishi, T.M., 2019. *Visualization of Ion Transport in Plants. In Agricultural Implications of the Fukushima Nuclear Accident* (III) (pp. 221-231). Springer, Singapore.
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- De Schepper, V., De Swaef, T., Bauweraerts, I. and Steppe, K., 2013. *Phloem transport: a review of mechanisms and controls. Journal of Experimental Botany*, 64(16), 4839-4850.
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- Mitra GN. *Regulation of Nutrient Uptake by Plants: A Biochemical and Molecular Approach*
- Uraguchi, S., Kamiya, T., Sakamoto, T., Kasai, K., Sato, Y., Nagamura, Y., Yoshida, A., Kyozuka, J., Ishikawa, S. and Fujiwara, T., 2011. *Low-affinity cation transporter (OsLCT1) regulates cadmium transport into rice grains. Proceedings of the National Academy of Sciences*, 108(52), pp.20959-20964.
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- Elanchezhian*et al*. 2015. *Physiological and molecular approaches for improving phosphorus uptake efficiency of crops. Current Science*, 108(7): 1271-1279.
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- Brian G. Forde (2000) *Nitrate transporters in plants: structure, function and regulation. Biochimica et Biophysica Acta* 1465: 219-235.
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I. Course Title : Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modelling

II. Course Code : PP 507

III. Credit Hours : 2+1

IV. Why this Course?

Agronomic inputs and environmental factors enhance crop growth by improving photosynthetic processes and photosynthate partitioning. Carbon metabolism is the most important physiological process that has a direct influence on crop growth and productivity which is quite sensitive to biotic and abiotic constraints. Hence a comprehensive understanding canopy photosynthetic process is crucial. This is an important component in crop improvement program, especially in the scenario of plateauing yields. These photosynthetic processes and their response to environmental factors form the basis for developing growth and yield predicting models.

V. Aim of the Course

The course provides a comprehensive theoretical and hands on experience and expertise to students on various aspects of photosynthesis including biophysical, biochemical and molecular regulations. While canopy photosynthesis drives crop growth rates, factors associated with sink activity and partitioning determine productivity. Hence, adequate emphasis would be given to canopy photosynthesis, translocation and its feedback regulation, Crop growth and yield structure analysis and their responses to environmental factors. Growth and yield prediction models and their relevance will be adequately discussed.

The course is organized as follows:

No.	Blocks	Units
1.	Photosynthetic Processes	1. Canopy Architecture and Energy Utilization 2. Photochemical Processes 3. Biochemical Processes 4. Product Synthesis and Translocation 5. Growth and Yield forming Mechanisms
2.	Yield Improvement and Modelling	1. Molecular Options to Improve Photosynthesis, Growth and Productivity 2. Fundamentals of Dynamic Simulation Models 3. Description of Well-established Yield Models 4. Examples of Robust Models Extensively Used

VI. Theory

Block 1: Photosynthetic Processes

Unit 1: Canopy Architecture and Energy Utilization

Parameters associated with canopy architecture that determine radiation interception and absorption, Energy absorption by primary and accessory pigments and energy utilization efficiency, Light distribution inside the canopy and concepts of light extinction coefficient.

Unit 2: Photochemical Processes

Ultrastructure of chloroplast: structure and composition of lamellar system, Components of electron transport, Water oxidation system and energy conservation processes, Pigment systems and the generation of a powerful oxidant and a powerful reductant, Chlorophyll fluorescence and fluorescence quenching: qN, qP, NPQ.

Unit 3: Biochemical Processes

CO_2 diffusion and resistances (g_s and g_m). Concept of Ci determining CO_2 diffusion. RuBisCO activation state, kinetics and catalytic properties, Carboxylation processes in C_3, C_4 and CAM plants and their relevance, CO_2 concentrating mechanisms and their importance in improving carbon assimilation, Ecological significance of C_4 and CAM photosynthesis, Photorespiration and Mitochondrial respiration and net carbon gain, Carbon isotope discrimination and its importance as a surrogate of Ci.

Unit 4: Product Synthesis and Translocation

Triose phosphate utilization and regulation of Calvin cycle mechanisms, Product synthesis and partitioning between starch and sucrose, Concepts of end-product inhibition or Pi-regeneration limitation, Phloem transport and factors that regulate phloem loading and un-loading.

Unit 5: Growth and Yield forming Mechanisms

Carbon gain and the concepts of Canopy photosynthesis. Relevance of LAI and LAD in determining total carbon gain and crop growth rates, Source: Sink relationship and its relevance in governing differences in crop growth rates and productivity. Concepts of HI and partitioning coefficient and remobilization of carbon from vegetative organs to reproductive structures, Growth analysis and parameters that explain growth rates: NAR, CGR, HI and their inter-dependence.

Block 2: Yield Improvement and Modelling

Unit 1: Molecular Options to Improve Photosynthesis, Growth and Productivity

Characteristic features of the Chloroplast genome: its structure and genes associated with various photosynthetic mechanisms, coordinated expression of chloroplast and nuclear genome for maintaining photosynthetic activities. Genomic and genetic resources such as specific genes and QTL associated with photosynthetic processes Transgenic options to enhance photosynthetic performance such as transferring genes to mitigate oxidative stress damage (SOD, APX, AKR etc), Theoretical concepts of crop improvement through inducing CCM in C_3 plants and reducing photorespiration.

Unit 2: Fundamentals of Dynamic Simulation Models

Collection of crop specific genetic coefficient, Crop, soil and historic weather data

Unit 3: Description of Well-established Yield Models

Application and limitations of modeling, Yield prediction models such as APSYM, PeanutGrowetc, Machine learning approaches and IoT for making informed on-farm decisions.

Unit 4: Examples of Robust Models Extensively Used

Duncan'syield prediction model, Passioura'smodelfor growth maximising.

VII. Practicals

- Plant sampling for leaf area and biomass estimation; analysis of growth and yield parameters – LAD, NAR. CGR, LAI, LAR, SLA portioning efficiency, HI.
- Measurement of light interception, light extinction coefficient, energy utilization efficiency based energy intercepted, and realized.
- Gas exchange: principles and uses to assess variations in CO_2 and water vapour transfer, determination of A/gs and intrinsic WUE
- Quantification of chlorophyll content by various methods: colorimetric and SPAD meter. The concept of SLN
- Chlorophyll fluorescence and quenching coefficients
- Theoretical aspects of carbon isotope fractional and its use in determining WUE
- Quantification of RuBisCO content by ELISA (if possible)
- Determination of RuBisCO activity and activation state using radioactive $CO\text{-}_2$
- CO_2 and light response curves and computation of carboxylation efficiency, quantum efficiency, relative limitations of photosynthesis at single leaf level.
- Adoption of crop models: Growth and yield prediction by Duncan's and Passioura's models

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

After completion of this course students are expected to have in depth knowledge on Photosynthetic processes associated with product synthesis and yield development. Students will also obtain current knowledge on various crop models.

X. Suggested Reading

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- Splinter, W.E. (1974). Modelling of plant growth for yield prediction. *Agricultural Meteorology*, 14(1-2), 243-253.

General Source Information

- Blankenship RE. 2014. *Molecular mechanisms of Photosynthesis* 2nd Edition
- *Canopy Photosynthesis: From Basics to Applications*. 2016 Ed Hikosaka, Kouki, Niinemets, Ülo, Anten, Niels P.R.

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I. Course Title : Physiology of Field Crops

II. Course Code : PP 508

III. Credit Hours : 2+0

IV. Why this course?

In recent years, phenomenal progress has been made in understanding plant processes which are crop specific. Genetic gain in productivity can be achieved only by improving plant physiological traits/adaptive mechanisms. Even crop management should be based on sound physiological principles. For example, crop's response to the increase in global warming has to be looked from thermo morphogenesis concept in terms of GDD and its effect on phenological processes in some of the important field crops exposure on crop specific physiological processes is necessary and has particular significance.

V. Aim of the course

This course provides a broad exposure on the physiological aspects of field crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of field crop plants. Besides, the emphasis is on unique crop specific features.

Broad categories of crops that can be selected for this course are as follows.

1. Cereals– Rice, Wheat, Maize etc.
2. Millets– Finger millet, Sorghum etc.
3. Pulse crops– Green gram, Black gram, Lentil, Pigeon pea, Chickpeas, Cowpea, Beans etc.
4. Oilseed crops– Groundnut, Rapeseed Mustard, Soybean etc.
5. Sugarcane
6. Fibre crops– Cotton, Jute, Ramie, Hemp etc.

The course is organized as follows:

No.	Blocks	Units
1.	Physiology of Field Crops	1. Introduction 2. Crop Establishment, Crop Growth and Development 3. Reproductive Growth 4. Seed Nutrient Quality 5. Plant Nutrition 6. Abiotic Stress Response 7. Crop Specific Physiological Processes and Importance

VI. Learning outcome

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of field crops.

VII. Theory

Block 1: Physiology of Field Crops

Unit 1: Introduction

Origin- Variability in physiology of crop plants between wild species and cultivated. Adaptability to growing environments (ecosystems), Importance in food grain contribution.

Unit 2: Crop Establishment, Crop Growth and Development

Seed characteristic features, dormancy, viability, concept of seed priming seedling establishment and crop stand. Different crop growth stages, concept of source establishment and optimum LAI, Canopy architecture, light interception/radiation use efficiency, thermal time, heat units, GDD, determining growth duration.

Unit 3: Reproductive Growth

Photo and thermo-periodic response for flowering, sink development, sink source relationship, partitioning efficiency, improvement in HI, yield determining factors, genetic gain in yield over years, structuring of ideal plant type, limitations to improve source to sink size, options to improve yield potential.

Unit 4: Seed Nutrient Quality

Seed quality, seed as a source of nutrients, seed constituents and their improvement, concept of pathway engineering to improve seed quality.

Unit 5: Plant Nutrition

Nutrient requirement, genetic variability in nutrient acquisition under constraint conditions, specific nutrient disorders.

Unit 6: Abiotic Stress Response

Response to different abiotic stresses, plant traits/mechanics to improve adaptation to realize potential yields. Global warming responses, thermomorphogenesis, approaches to overcome the constraints.

Unit 7: Crop Specific Physiological Processes and Importance

Choosing location specific crop species exposure will be given on physiological process as described above. Besides, emphasis is on providing information on crop specific features/productivity constraints.

Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

Suggested Reading

- *Grain Legumes*: Ed De Ron, Antonio M. (Ed.) 2015. Springer
- *Legumes under Environmental Stress: Yield, Improvement and Adaptations*. Eds MM Azooz P Ahmad and Hoboken, NJ: John Wiley and Sons, Ltd., 328 pages. ISBN: 978-1-118-91708-4
- *Pulse Crops: Biotechnological Strategies to Enhance Abiotic Stress Tolerance*. Ganeshan S, Gaur PM, Chibbar RN, Tuteja N, Gill SS, Tuteja R. chapter 17
- *Climate Change and Management of Cool Season Grain* Legume *Crops*. Eds Yadav GS, McNeil DL, Redden R, Patil SA. Springer
- *Nature's pulse power: legumes, food security and climate change.* Considine MJ, Siddique

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- Pandey V and Shukla A. 2015. *Acclimation and Tolerance Strategies of Rice under Drought Stress. Rice Science* 22(4): 147-161.
- Kole C. 2006. *Cereals and millets. Genome Mapping and Molecular Breeding in Plants. Springer*.
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- Mamrutha HM *et al*. 2019. *Physiological and Molecular Basis of Abiotic Stress Tolerance in Wheat*. In: Rajpal V., Sehgal D., Kumar A., Raina S. (eds) *Genetic Enhancement of Crops for Tolerance to Abiotic Stress: Mechanisms and Approaches*, Vol. I. Sustainable Development

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- Tiwari V. *et al*. 2017. *Managing Abiotic Stresses in Wheat*. In: Minhas P., Rane J., Pasala R. (eds) *Abiotic Stress Management for Resilient Agriculture*. Springer, Singapore

I. Course Title : Physiology of Horticulture Crops
II. Course Code : PP 509
III. Credit Hours : 2+0

IV. Why this Course?

Improving physiological processes forms the basis to enhance the productivity or to improve a specific growth processes. Several interventions based on principals of physiological processes provide options to enhance crop productivity. Basic insight on photoperiodic response is crucial for determining planting dates. Understanding the mechanisms of rooting for vegetative propagation has lead in developing rooting hormones etc., In view of this, a comprehensive exposure on growth and development of horticulture crops and providing insights on major production constraints and physiological approaches to overcome is highly essential.

V. Aim of the Course

This course should provide a broad exposure on the physiological aspects of horticulture crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of horticultural crop plants. To describe basic and applied physiology behind the production and productivity of horticultural crops and their pre and postharvest management, ideal storage conditions, quality retention, processing and value addition.

Broad categories of crops that can be selected for this course are as follows.
1. Fruit crops: Mango, Grapes, Apple, Banana, Citrus etc.
2. Vegetable crops: Tomato, Onion, Brinjal, Cauliflower, Okra etc.
3. Tuberous crops: Potato, Cassava, Sweet potato, Yam etc.
4. Plantation crops: Coconut, Oil palm, Cashew, Tea, Coffee, Rubber, Areca nut, Cocoa etc.
5. Floriculture crops: Rose, Marigold, Carnation, Chrysanthemum, Gladiolus, Orchids, Tuberose etc.
6. Other groups: Medicinal crops, Aromatic crops, Spices crops.

The course is organized as follows:

No.	Blocks	Units
1	Physiology of Horticultural Crops	1. Introduction 2. Crop growth and Development 3. Reproductive Growth 4. Pre and Post-harvest Physiology 5. Plant Nutrition and Abiotic Stress Responses 6. Specific Aspects and Unique Crop Features

VI. Learning outcome

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of horticultural crops.

VII. Theory

Block 1: Physiology of Horticultural Crops

Unit 1: Introduction

Origin, distribution and adaptability of crops to different agro-climatic conditions

Unit 2: Crop growth and Development

Internal factors (hormone, etc.) influencing various physiological processes linked to vegetative growth or growth of specific organ, correlative and algometric growth External factors (water, nutrition, temperature, etc.) influencing various physiological processes linked to vegetative growth or growth of specific organ, correlative and algometric growth, Propagation methods, grafting, cutting, budding, air layering. Physiology of pruning, dwarfing, branch bending, canopy management etc., Physiological and biochemical aspects of scion and root stock interaction and compatibility.

Unit 3: Reproductive Growth

Physiology of flowering, photo- and thermo-periodism and response to vernalization, Factors influencing reproductive growth, fruit and seed set/retention, physiology of flower sex ratio, Physiological processes governing source-sink relationship and productivity.

Unit 4: Pre and Post Harvest Physiology

Preharvest factors influencing postharvest physiology, Physiological and molecular mechanisms of ripening, Physiological and molecular mechanisms of senescence, Hormonal and chemical control of postharvest deterioration of fruits/vegetable/ flowers. Regulation of ripening at physiological and molecular levels, Regulation of senescence at physiological and molecular levels, Approaches to improve shelf life and storability. Approaches to improve postharvest management, Approaches to improve processing and value addition.

Unit 5: Plant Nutrition and Abiotic Stress Responses

Nutrient acquisition and requirement, plant phenology and nutrient requirement; Role of rootstocks in nutrient acquisition and in abiotic stress tolerance, Adaptive mechanisms and approaches to improve performances under drought and high temperature, Adaptive mechanisms and approaches to improve performances under frost, chilling and nutrient deficient conditions, Root physiology in abiotic stress tolerance.

Unit 6: Specific Aspects and Unique Crop Features

Specific aspects

Polyhouse cultivation, Hormones/PGRs for improving crop performance, Major and micronutrients for improving crop performance, Light interception, shade regulation, dwarfing root stocks, Chilling requirement for flowering, photoperiodic response, pollen viability, stigma receptivity, Flower (blossom) and fruit drop.

Unique crop features

Maturity and maturity indices, Source-sink relations, Vegetative propagation, Physiology of tuberization and rhizome initiation and formation, Virus free planting material, Bulbs/tubers dormancy, bud break, Physiological disorders, Storage, Packaging, Quality.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

IX. Suggested Reading

- Sethuraj MR and Raghavendra AS. 2012. *Tree Crop Physiology*. ISBN-13: 978-0444428417, ISBN-10: 0444428410, Elsevier Science Publishers.
- Bhatnagar P. *Physiology of Growth and Development of Horticultural Crops*, ISBN-10: 817754666X, ISBN-13: 978-8177546668
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- Hare K. 2012. *Physiology of Fruit Production*, ISBN-10: 9380012373, ISBN-13: 978-9380012377, Studium Press India Pvt. Ltd
- Durner EF. 2013. *Principles of Horticultural Physiology*, ISBN-13: 978-1780643069, ISBN-10: 1780643063, CABI.
- Bleasdale JKA. *Plant Physiology in Relation to Horticulture*, ISBN-10: 8192686094, ISBN-13: 978-8192686097, SENTIFIC (2014) 2nd edition
- Kumar M. 2015. *Physiology of Fruit Production*, ISBN-10: 9384568384, ISBN-13: 978-9384568382.
- Yahia EM and Carrillo-Lopez A. 2018. *Postharvest Physiology and Biochemistry of Fruits and Vegetables*, ISBN-10: 0128132787, ISBN-13: 978-0128132784, Woodhead Publishing.
- Freitas ST and Pareek S. *Postharvest Physiological Disorders in Fruits and Vegetables*, ISBN-9781138035508, 1138035505,Taylor and Francis Ltd.
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- Carr MKV. 2014. *The water relations and irrigation requirements of mango (Mangifera indica L.): a review. Experimental Agriculture,* 50(1), 1-23.
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- Ramírez F and Davenport TL. 2010. *Mango (Mangifera indica L.) flowering physiology. Scientia Horticulturae*, 126(2), 65-72.
- Léchaudel M, Lopez-Lauri F, Vidal V, Sallanon H and Joas J. 2013. *Response of the physiological parameters of mango fruit (transpiration, water relations and antioxidant system) to its light and temperature environment. Journal of plant physiology,* 170(6), 567-576.
- Urban L, Jegouzo L, Damour G, Vandame M and François C. 2008. *Interpreting the decrease in leaf photosynthesis during flowering in mango. Tree physiology*, 28(7), 1025-1036.
- Jameel MA, Naik SR, Madhumathi C, Reddy DS and Venkataramana KT. 2018. *Physiology of flowering in mango. Journal of Pharmacognosy and Phytochemistry*, 7(6), 2375-2382.
- Lin HL, Shiesh CC and Chen PJ. 2012. *May. Physiological disorders in relation to compositional changes in mango (Mangiferaindica L.'Chiin Hwang') fruit. In VII International*

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- Dayal V, Dubey AK, Singh SK, Sharma RM, Dahuja A and Kaur C. 2016. *Growth, yield and physiology of mango (Mangifera indica L.) cultivars as affected by polyembryonic rootstocks. Scientia horticulturae*, 199, 186-197.

Grapes

- Keller M. 2015. *The science of grapevines: anatomy and physiology*. Academic Press.
- Williams LE. 2017. *Grape. In Photoassimilate Distribution Plants and Crops Source-Sink Relationships* (pp. 851-882). Routledge.
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Guava

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- Adhikari S and Kandel TP. 2015. *Effect of time and level of pruning on vegetative growth, flowering, yield, and quality of guava. International Journal of Fruit Science*, 15(3) 290-301.
- Sharma S, Sehrawat SK and Sharma KD. 2017. *Studies on time and duration of flowering, floral bud development and morphology of guava (psidiumguajava l.) Under semi-arid region of india. Int. J. Curr. Microbiol. App. Sci,* 6(12). 4176-4186.
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- Adhikari S. 2012. *Guava Pruning and Its Physiology*

Tomato

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Onion

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- Khokhar KM. 2014. *Flowering and seed development in onion—A review.* Open Access Library 1(07).

Brinjal

- Sharma SP and Brar JS. 2008. *Nutritional requirements of brinjal (Solanum melongena L.)-A review. Agric. Rev,* 29(2), pp.79-88.
- Byari, S.H. and Al-Rabighi, S.M., 1995. *Morphological and physiological responses of egg plant cultivars (Solanum melongena L.) to drought*. J. KAU: *Met. Env, Arid Land Agric. Sci*, *6*, pp.41-47.

I. Course Title : Seed Physiology

II. Course Code : PP 510*

III. Credit Hours : 2+1

IV. Why this course?

Seeds are considered as propagule and as a major source of nutrition for humans and other animals. Therefore, all information concerning their nutritive value, chemical composition; storability, retention of viability are very important. Looking into the importance of seeds, emphasis has been given to produce high quality seeds with excellent genetic potential to improve seed germination and to produce vigorous seedlings. In fact, recently techniques are employed to raise healthy and vigorous seeds to obtain vigorous seedlings. Several hormones and chemicals are used to improve the oil, protein, and other economic attributes of seeds. Therefore, to give more insight into the development of quality seeds and also protecting them without losing much of nutritive value, this course has been proposed.

V. Aim of the course

This course will approach the subjects from two perspectives –physiology of seed development and seed germination. It aims to describe students the physiological processes involved in regulation and mechanism of seed development, dormancy and germination. Further, to provide an insight into physiological processes governing seed quality and its survival. Accordingly.

The course is organized as follows:

No.	Blocks	Units
1.	Physiology of Seed Development	1. Introduction to Seed Physiology 2. Seed Development 3. Seed Maturation 4. Metabolism in Developing Seed
2.	Physiology of Seed Germination and Dormancy	1. Seed Germination 2. Seed Dormancy and Viability

VI. Theory

Block 1: Physiology of Seed Development

Unit 1: Introduction to Seed Physiology

Importance of seed as a propagule, seed structure and functions; chemical composition of seeds. Embryogenesis: pollination and fertilization, pollen and pistil interaction, signal for interaction; pollen load hypothesis; genetical and environmental influence on seed development. Source-Sink relationship affecting seed yield and quality. Concept of seed viability and seedling vigour and their relevance; approaches to improve the storability of seeds. Physiological and molecular mechanisms of seed germination; approaches to improve seed germination; seed size and its influence on seed germination.

Unit 2: Seed Development

Physiology and molecular mechanisms of embryo, endosperm and seed coat development; cellularization during endosperm development; morphological and cellular changes during seed coat development, anatomy and function of seed coat, programmed cell death (PCD) in seed coat, Deposition of seed storage reserves during development.

Unit 3: Seed Maturation

Seed maturation and maturation indices; physiological and anatomical changes during seed maturation; Seed drying and acquisition of desiccation tolerance in seeds; mechanisms of desiccation tolerance; role of ABA LEA's, HSP's, dehydrins and other stress proteins during seed maturation and drying, Seed abortion and approaches to reduce it.

Unit 4: Metabolism in Developing Seed

Chemical composition of seeds (carbohydrates, proteins, fats etc.), source of assimilates for seed development, pathways of movement of assimilates to developing seed, approaches to increase the chemical composition of seeds. Seed respiration and mitochondrial activity; seed respiration rate and storability of seeds. Seed ageing, Mobilization of stored resource in seeds; Chemistry of oxidation of starch, proteins and fats; Utilization of breakdown products by embryonic axis.

Block 2: Physiology of Seed Germination and Dormancy

Unit 1: Seed germination

Seed germination, types of germination, imbibition kinetics of germinating seed; Physiological events during germination: seed respiration, mitochondrial activity, mobilization of food reserve; energy utilization by the germinating seed.

Environmental regulation of germination: hydro-time, thermal time and hydrothermal time models; Influence of environmental factors on germination; Role of plant hormones/PGR's during seed germination.

Unit 2: Seed Dormancy and Viability

Physiological and molecular basis of seed dormancy, hormonal regulation of dormancy, After ripening, dormancy breaking treatments; Ecological perspective of seed dormancy. Seed viability: concept and physiology of seed viability, theories of seed ageing, seed storage and regulation of storage life of seeds; methods to prolong seed viability; Conservation of orthodox and recalcitrant seeds. Seed vigour: concept, importance, measurement; Physiological, biochemical and molecular basis of seed vigour.

VII. Practicals

- Determination of seed reserves: carbohydrates, proteins and lipids
- Study of different seed structures
- Kinetics of seed imbibition; Seed germination test, enzymatic activities and respiration during germination and vigour testing methods etc.
- Accelerated ageing test to know the seed vigour and storability
- Measurement of seed moisture content
- Determination of amylase activity in germinating seeds
- Measurement of electrical conductivity in seed leachate
- Measurement of seed viability using tetrazolium chloride
- Determination of dehydrogenase activity
- Seed germination study- Determination of Germination Index and seedling growth
- Measurement ofseed vigour index
- Dormancy breaking treatments
- Seed priming techniques
- Effect of environmental stresses on seed germination and seedling growth
- Effect of hormones on seed germination

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

At the end of the course the students are expected to be able to understand the physiology of seed development and seed germination. The students will be able to identify the physiological processes involved in regulation of seed development, dormancy and germination.

IX. Suggested Reading

- Bewley, JD, Bradford K, Hilhorst H, Nonogaki H. (2013). *Seeds: Physiology of Development, Germination and Dormancy*, Springer-Verlag.
- Larkins BA and Vasil IK (Ed), *Cellular and Molecular Biology of Plant Seed Development*, 2010, Springer.
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- Pammenter NW and Patricia Berjak. 2000. *Aspects of recalcitrant seed physiology*. R.Bras. Fisiol. Veg., 12: 56-69.

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- Roberto Benech-Arnold, Rodolfo Sanchez. 2004. *Handbook of Seed Physiology: Applications to Agriculture*. CRC Press.
- Vijayakumar A. 2001. *Seed Dormancy an overview. In: Recent techniques and Participatory Approachs in Quality seed production* (eds. K. Vanangamudi *et al.*) TNAU, Coimbatore. 287-396.
- Padmavathi SM, Prakash S, Ezhil Kumar G, Sathianarayanan and Kamaraj A. 2012. *A Text Book of Seed Science and Technology*. New India Publishing Agency, New Delhi.
- Tina Steinbrecher Gerhard Leubner-Metzger. 2017. *The biomechanics of seed germination. Journal of Experimental Botany*, 68(4): 765–783.
- http://sbc.ucdavis.edu/Research_pages/Seed_physiology_and_technology/.
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I. Course Title : Phenotyping Physiological Processes

II. Course Code : PP 511

III. Credit Hours : 2+0

IV. Why this course?

One of the main mandates of SAU and crop specific institutes is crop improvement. Seed industry and academic institutes need contribution from physiologists on these aspects. Conceptual changes in breeding approaches in terms of breeding for specific physiological traits necessitates that the students develop conceptual approaches for phenotyping in different physiological processes. Characterizing the parents, germplasm accessions, segregating populations for specific physiological traits like flowering response, variation in root system architecture, etc is crucial for genetic enhancement of these traits. This student ready Course can contribute richly to research and development of the seed sectors and crop specific institutions where the major emphasis in recent years is genetic enhancement of traits.

V. Aim of the course

The major emphasis in this course is to phenotype well characterized physiological processes/plant traits associated with plant growth, development and productivity, besides, comprehensive approach to precise imposition of various abiotic stresses and capture genetic variability in adaptive traits. The aim is to employ these techniques for crop improvement programs.

The course is organized as follows:

No.	Blocks	Units
1.	Phenotyping Physiological Processes	1. Concept of Phenotyping 2. Phenotyping for Traits for Crop Establishment 3. Concept and Approaches to Identify Genotypes with Superior Growth Rate 4. Identifying Photo-insensitive Genotypes-options and Approaches 5. Identifying Thermo-insensitive Genotypes-options and Approaches 6. Yield Structure Analysis- Relevant Yield Attributes 7. Source-sink Relationship- Assessment of Limitation

No.	Blocks	Units
		8. Identify Genetic resources for Abiotic Stress Constraints

VI. Theory

Block 1: Phenotyping Physiological Processes

Unit 1: Concept of Phenotyping

Phenotyping technologies are essential component for assessing plant responses, identify superior trait donors, mitigation responses, trait introgression and trait based breeding.

Unit 2: Phenotyping for Traits for Crop Establishment

Seed viability, seed dormancy, seed hydration rates, seed density and weight, Seedling vigour in normal and adverse conditions.

Unit 3: Concept and Approaches to Identify Genotypes with Superior Growth Rate

Phenotyping for leaf expansion, leaf area index, light interception and crop extinction coefficient. Pigment quantification for nitrogen and chlorophyll status - SPAD, anthocyanin and flavonoids – Duolex. Growth rates by non-invasive techniques like NDVI, Concept of Net assimilation rate and DM/LAD; surrogates for photosynthetic traits; stomatal characteristic.

Unit 4: Identifying Photo-insensitive Genotypes-options and Approaches

Exposing to longer and shorter photoperiod by staggered sowing; extending the day length- light interception by red light; days to heading/ anthesis, approaches for synchronization of flowering.

Unit 5: Identifying Thermo-insensitive Genotypes-options and Approaches

Altering total degree days- staggered sowing at lower latitudes or by growth chambers; quantifying heading, anthesis, maturity and grain filling days, grain number and weight, grain filling rate.

Unit 6: Yield Structure Analysis- Relevant Yield Attributes

Pollen biology, stigma receptivity, spikelet sterility (cereals), floral abscission (other crops), fruiting points / productive tillers, number of grains/ fruits per panicle/ inflorescence and grain characteristic. Phenotyping for lodging- culm traits, intermodal length, lignification, Phenylalanine ammonia lyase (PAL) and Tyrosine ammonia lyase(TAL). Approaches to identify genetic resources with traits to improve yield potential.

Unit 7: Source-sink Relationship- Assessment of Limitation

Phenotyping for source-sink size, Concept of sink-source limitation- defloration and defoliation. Remobilization of stored metabolites and concept of stay green; estimation of water soluble carbohydrates; partitioning coefficient and harvest index.

Unit 8: Identify Genetic Resources for Abiotic Stress Constraints

Approaches for precise stress imposition to diverse stresses, Identify trait donor lines for different stresses: approaches by Stress Susceptibility Index (SSI), Stress Induction Response (SIR), Capturing variability for adaptive traits: root traits, stomatal factors/wax, osmolyte, surrogate approach for acquired tolerant traits, Flowering response, Spikelet fertility, Abscission and Senescence, Screening high density response-based on SSI – root adaptation and Shade Avoidance Response (SAR).

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Learning outcome

After completion of this course students are expected to develop clear concept and insight into phenotyping technologies associated with plant growth, development and productivity.

IX. Suggested Reading

- Kumar J, Pratap A and Kumar S. 2015. *Plant Phenomics: An Overview*. 10.1007/978-81-322-2226-2_1.
- Pratap A, Gupta S, Nair RM, Gupta SK, Schafleitner R, Basu PS, Singh CM, Prajapati U, Gupta AK, Nayyar H, Mishra AK, Baek KH. 2019. *Using Plant Phenomics to Exploit the Gains of Genomics. Agronomy* 9, 126.
- AOSA. 2009. *Seed Vigor Testing Handbook. Contribution No. 32 to the Handbook on Seed Testing*.
- Finch-Savage WE and Bassel GW. 2015. *Seed vigour and crop establishment: extending performance beyond adaptation. Journal of experimental botany*, *67*(3), 567-591.
- Muñoz-Huerta R, Guevara-Gonzalez R, Contreras-Medina L, Torres-Pacheco I, Prado-Olivarez J and Ocampo-Velazquez R. 2013. *A review of methods for sensing the nitrogen status in plants: advantages, disadvantages and recent advances. sensors*, 13(8), 10823-10843.
- Xue, J and Su B. 2017. *Significant Remote Sensing Vegetation Indices: A Review of Developments and Applications, Journal of Sensors*, 2017: 17 https://doi.org/10.1155/2017/1353691.
- Ouzounis, T., Rosenqvist, E., and Ottosen, C., 2015. *Spectral Effects of Artificial Light on Plant Physiology and Secondary Metabolism: A Review American Society Horticulture Science.* 50(8); 1128–1135 doi.org/10.21273/HORTSCI.50.8.1128
- *The Flowering Response of the Rice Plant to Photoperiod: A Review of The Literature* Fourth Edition.
- Sehgal A, Sita K, Siddique KH, Kumar R, Bhogireddy S, Varshney RK and Nayyar H. 2018. *Drought or/and Heat-Stress Effects on Seed Filling in Food Crops: Impacts on Functional Biochemistry, Seed Yields, and Nutritional Quality. Frontiers in Plant Science*, 9.
- Prasad, P. V., Bheemanahalli, R., andJagadish, S. K. 2017. *Field crops and the fear of heat stress—Opportunities, challenges and future directions. Field Crops Research* 200, 114-121.
- Gómez JF, Talle B and Wilson ZA. 2015. Anther and pollen development: a conserved developmental pathway. *Journal of Integrative Plant Biology* 57(11), 876-891.
- Khobra R, Sareen S, Meena BK, Kumar A, Tiwari V and Singh GP. 2019. *Exploring the traits for lodging tolerance in wheat genotypes: A review. Physiology and Molecular Biology of Plants*, 1-12.

  Hirano K, Ordonio RL and Matsuoka M. 2017. *Engineering the lodging resistance mechanism of post-Green Revolution rice to meet future demands. Proceedings of the Japan Academy, Series B*, 93(4), 220-233.

  White, A. C., Rogers, a., Rees, M and Osborne, C.P., 2016. *How can we make plants grow faster? A source–sink perspective on growth rate Journal of Experimental Botany*, 67(1): 31–45.

  Ragheba, A., El-Shimyb, H and Raghebb, G. 2016. *Green architecture: a concept of sustainability, Procedia - Social and Behavioral Sciences* 216: 778 – 787.

- Wang H, Wu G, Zhao B, Wang B, Lang Z, Zhang C and Wang H. 2016. *Regulatory modules controlling early shade avoidance response in maize seedlings*, *BMC Genomics* **17**: 269, https://doi.org/10.1186/s12864-016-2593-6.
- Carriedo, L., Maloof, J and Brady, S. 2016. *Molecular control of crop shade avoidance. Current Opinion in Plant Biology*. 30. 151-158. 10.1016/j.pbi.2016.03.005.

I. Course Title : Crop Growth Regulation and Management

II. Course Code : PP 512

III. Credit Hours : 2+0

IV. Why this Course?

Besides crop improvement, the approach to regulate physiological processes for improving crop production made very good leads in recent years. The focus is to employ the basic knowledge of several physiological processes to manipulate the plant growth and specific processes like ripening, flowering to achieve higher economic yields. This dynamic course will address many of these technologies that are being developed for crop production based on principles of plant physiological processes. Training the students in this student ready coursewill provide the required practical knowledge which will be of immense relevance to contribute private agricultural sectors and for agri-based industries.

V. Aim of the Course

A comprehensive information needs to be provided in this course like light regulation in polyhouse cultivation, photoperiod responses by red/far red light for synchronizing flowering, techniques for soil less culture like aeroponics, pollen biology and hybrid production, chemical regulation of plant growth processes like flower initiation, flower sex, flower drop, fruit maturity, ripening and shelf-life, etc.

The course is organized as follows:

No	Blocks	Units
1	Propagation - Crop Establishment	1. Seed as a Propogule 2. Vegetative Propogule
2	Regulation of Plant Growth Processes	1. Regulation of Plant Growth and Flowering 2. Fruit Ripening and its Regulation 3. Concept of Senescence and its Retardation
3	Protective Cultivation–Stress Mitigation	1. Protective Cultivation Interventions to Alter Physiological Processes and Growth 2. Drought Mitigation Options and Approaches 3. Specific Plant Processes Regulated by Chemicals and Growth Hormones

VI. Theory

Block 1: Propagation - Crop Establishment

Unit 1: Seed as a Propogule

Concept of improving seed characteristics for crop establishment. Mechanisms of regulating seed dormancy, precocious germination, ways to control pre-harvest sprouting in crop plants. Seed viability and its regulation, factors to minimize loss of viability and improve seedling vigour. Concept of seed priming, techniques of priming, seed priming to induce tolerance to stresses. Role of media, nutrition and PGPR's on seedling vigour and subsequent crop establishment.

Unit 2: Vegetative Propogule

Chemical and hormonal regulation of vegetative propagation. Regulation of rooting, bud sprouting, Bulb/tuber dormancy. Chemical regulation of graft union. Concept of *in vitro* micropropogation.

Block 2: Regulation of Plant Growth Processes

Unit 1: Regulation of Plant Growth and Flowering

Chemical and hormonal regulation of plant architecture, tillering, branching, bud breaking, Regulation of flowering by photo and thermoperiod, nutrients, chemicals and hormones, concept of speed breeding, Flowering synchrony in hybrid seed production, Sex ratio alteration, flower and fruit thinning, Pollen viability in relation to environment, harvesting, storage and transportation, Prevention of abscission, flower and fruit drop, seed and fruit growth regulation- role of hormones.

Unit 2: Fruit Ripening and its Regulation

Approaches to improve shelf life – storage environment, water loss, respiration, Modified atmosphere, gaseous environment for storage, storage disorders, chilling injury.

Unit 3: Concept of Senescence and its Retardation

Physiology of senescence and options to regulate, Chemical regulation of senescence, maintenance of chlorophyll during storage, role of hormones/micronutrients in reducing senescence, Concept of stay green, advantages and limitations. Relevance of stay green traits in plant breeding for crop improvement.

Block 3: Protective Cultivation–Stress Mitigation

Unit 1: Protective Cultivation Interventions to Alter Physiological Processes and Growth

Spectral characteristics of light in polyhouse, light regulation to optimize plant photosynthetic and photomorphogenic processes and plant growth, LED sources of monochromatic light to regulate growth, etiolating and flowering, High temperature induced thermomorphogenic processes, Artificial growing media, soilless cultures, aeroponics, fogoponics, Concept of CO_2 fertilization. Effect of humidity on leaf expansion and growth.

Unit 2: Drought Mitigation Options and Approaches

Moisture conservation options at soil and plant level, Concept of increasing water holding capacity, role of Hydrogels – water and mineral nutrients release pattern. Approaches to improve transpiration over evapo-transpiration, stomatal and non-stomatal regulation of water loss, antitranspirants, Osmoprotectants, ROS scavengers, plant nutrients, Root stocks in improving tolerance, Chemical regulation of flower drop due to temperature, Chemicals to improve pollen viability during abiotic stress.

Unit 3: Specific Plant Processes Regulated by Chemicals and Growth Hormones

Rooting of cuttings, Wine brewing industry, Promotion of gynoecious flower, Hybrid rice production, Induction of flowering in pine apple, cucurbits, Delaying of senescence and ripening, Production of dwarf plant for ornamental purpose, Reduction in flower and fruit drop, Increase in berry size in grapes.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Suggested Reading

- Wu X, Ning F, Hu X and Wang W. 2017. *Genetic Modification for Improving Seed Vigor Is Transitioning from Model Plantsto Crop Plants. Front. Plant Sci.* 8: 8. doi: 10.3389/fpls.2017.00008
- William E. Finch-Savage and Steven Footitt. 2017. *Seed dormancy cycling and the regulation of dormancy mechanisms to time germination in variable field environments Journal of Experimental Botany*, 68, (4), 843 856, https://doi.org/10.1093/jxb/ erw477
- Afzal I, Ur Rehman H, Naveed M and ShahzadMaqsood, Basra A. 2016. *Recent Advances in Seed Enhancements* Intech.
- *Techniques and Experiments Plant Tissue Culture Techniques and Experiments* Elsevier Inc. 2013.
- Nanda AK and Melnyk CW. 2018. *The role of plant hormones during grafting. Plant Res.* 131(1): 49–58. doi: 10.1007/s10265-017-0994-5PMCID: PMC5762790
- Casa JJ and Balasubramanian. SK 2019. *Thermomorphogenesis, Annual Review of Plant Biology*, 70: 321-346 https://doi.org/10.1146/annurev-arplant-050718-095919
- Halevy AH. 2018. *Handbook of Flowering*. V*CRC press*
- Watson A, Ghosh S, Lee T. Hickey. 2018. *Speed breeding is a powerful tool to accelerate crop research and breeding. Nature Plants* 4, 23–29.
- Kusumaningrum D, Lee SH, Lee WH, Mo C., and Cho, B. K. 2015. *A review of technologies to prolong the shelf life of fresh tropical fruits in Southeast Asia. Journal of Biosystems Engineering* 40(4), 345-358.
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- Falagán, N and Terry LA. 2018. *Recent advances in controlled and modified atmosphere of fresh produce. Johnson Matthey Technology Review* 62(1), 107-117.
- Kim, J., Kim, J. H., Lyu, J. I., Woo, H. R., and Lim, P. O. 2017. *New insights into the regulation of leaf senescence in Arabidopsis. Journal of experimental botany* 69(4), 787-799.
- Luche, H. D. S., Silva, J. A. G. D., Maia, L. C. D., and Oliveira, A. C. D. 2015. *Stay-green: a potentiality in plant breeding. Ciência Rural*, *45*(10), 1755-1760.
- Bian, Z., Jiang, N., Grundy, S. and Lu, C., 2017. *Uncovering LED light effects on plant growth: new angles and perspectives-LED light for improving plant growth, nutrition and energy-use efficiency*. In *International Symposium on New Technologies for Environment Control, Energy-Saving and Crop Production in Greenhouse and Plant* 1227. 491-498.
- Barrett, G.E., Alexander, P.D., Robinson, J.S. and Bragg, N.C., 2016. *Achieving environmentally sustainable growing media for soilless plant cultivation systems–A review. Scientia horticulturae*, 212: 220-234.
- Raviv, M., Lieth, J.H. and Bar-Tal, A. (eds), 2019. *Soilless Culture: Theory and Practice: Theory and Practice*. Elsevier.
- Wang, P., Deng, Y., Li, X.Y., Wei, Z., Hu, X., Tian, F., Wu, X., Huang, Y., Ma, Y.J., Zhang, C. and Wang, Y. 2019. *Dynamical effects of plastic mulch on evapotranspiration partitioning in a mulched agriculture ecosystem: Measurement with numerical modeling. Agricultural and Forest Meteorology*, 268: 98-108.
- GernotBodner, Alireza, Hans-Peter *Management of crop water under drought: A review. Agronomy for sustainable development*. 2: 401-442

Course Title with Credit Load
Ph.D. Plant Physiology

Course Code	Course Title	Credit Hours
PP 601	Functional Genomics and Genes Associated with a Few Physiological Processes	2+0
PP 602*	Signal Perceptions and Transduction and Regulation of Physiological Processes	2+0
PP 603	Molecular Approaches for Improving Physiological Mechanisms Through Trait Introgression	2+1
PP 604	Plant Phenomics – Next Generation Phenomics Platforms	2+0
PP 605	Experimental Techniques to Characterize Plant Processes for Crop Improvement	0+2
PP 606	Global Climate Change and Crop Response	2+0
PP 607*	Physiological and Molecular Aspects of Source-sink Capacity for Enhancing Yield	3+0
PP 608	Seed and Fruit Growth and their Quality Improvement	2+0
PP 609	Plant-microbe Interactions	2+1
PP 610	Weed Biology and Physiology of Herbicide Action	2+0
PP 691	Doctoral Seminar I	1+0
PP 692	Doctoral Seminar II	1+0
PP 699	Doctoral Research	75

*Core courses

Course Contents
Ph.D. in Plant Physiology

I. Course Title : Functional Genomics and Genes Associated with a Few Physiological Processes

II. Course Code : PP 601

III. Credit Hours : 2+0

IV. Why this Course?

Agriculture in India faces tremendous challenges on multiple fronts. There is a need for targeted improvement of crops to meet the increasing food demand. Thorough understanding of the plant physiological processes, pathways and genes associated with the pathways are needed for speed breeding and trait improvement. With help of modern tools and techniques, in the genomic ear, a large amount of data on genomic resources has been developed. The post-genomic era concentrates on assigning functions to the every gene identified in plants. The PhD scholar working on plant biology and related field must be exposed to recent trends and developments in this new emerging area. The major emphasis would be on new developments in genomics to regulate plant growth.

V. Aim of the Course

The major goal is to expose the students of higher education program on functional genomic approaches, which is needed for crop improvement in a targeted way:

(i) Identify genes regulating the specific mechanisms/traits.

(ii) Assess the relevance of physiological processes/mechanisms and options to combine/ introgress them.

The course is organized as follows:

No.	Blocks	Units
1.	Functional Genomics and Genes: Physiological Processes	1. Gene Discovery 2. Genetic Tools for Plant Development 3. Gene Knock Out Approaches 4. Chemical Genomics 5. Gene Over Expression Approaches 6. Synthetic Biology and Interaction Studies 7. Case Studies

VI. Theory

Block 1: Functional Genomics And Genes: Physiological Processes

Unit 1: Gene Discovery

Finding genes in complex plant system, Constructing gene-enriched plant genomic libraries, Recent advancements in genome sequencing, RNA sequencing and expression, In Silico prediction of plant gene function, Quantitative Trait Locus analysis as a gene discovery tool, Gene expression analysis –micro-array and deep sequencing, small RNA and Degradome, Study of methylome and its significance

Unit 2: Genetic Tools for Plant Development

Understanding the importance of mutants in unrevealing the physiological processes, genome wide insertional mutagenesis – T-DNA insertion mutants, Gain in function, Transposon mutagens, Transposition, Physical and Chemical mutagenesis, Gene and Enhancer Traps for Gene Discovery, High-Throughput TAIL-PCR as a Tool to identify DNA Flanking insertions, High-Throughput TILLING for functional Genomics, Genome editing approaches for functional analysis of genes.

Unit 3: Gene Knock Out Approaches

PTGS-Antisense technology, Virus induced gene silencing (VIGS), Custom Knock-outs with Haripin RNA-mediated Gene Silencing and other silencing tools, Complementation studies.

Unit 4: Chemical Genomics

Reverse chemical genomic approaches for functional validation of genes, Protein structure prediction, homology modelling and virtual screening by using bioinformatic approaches to identify the small molecules and their validation through phenotyping assessment.

Unit 5: Gene Over Expression Approaches

Vector Construction for Gene Overexpression as a Tool to Elucidate Gene Function Transient expression, Transgenics, Targeted and conditional expression of transgene. Multiple gene expression by Nanostring technology, Co-expression analysis and gene networking to identify potential genes in the pathway (informatics), Epigenetics.

Unit 6: Synthetic Biology and Interaction Studies

Engineering microbial pathways in plants (eg, photosynthesis), DNA-protein & Protein-protein interaction studies, yeast hybrid system, Correlating the data from genome, transcriptome, proteome, metabolome and ionome with phenome, Multivariate analysis and identification of metabolite as biomarkers.

Unit 7: Case Studies

Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling photosynthesis and nutrient uptake, Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling respiration and photorespiration, Functional characterization of genes associated with important cellular processes influencing crop growth and development: fatty acid biosynthesis, seed protein quality and quantity, Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling flowering.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Learning outcome

After successful completion of this course students are expected to have in depth knowledge on the genetic tools for plant development.

IX. Suggested Reading

Regulation of Gene Expression in Plants*. Gatehouse JA. 1997. *Plant Biochemistry.

Plant genome sequencing, Fleury D, Langridge P. 2012. *Plant Biotechnology and Agriculture*.
Baxevanis, A. D. and Ouellette, B. F. F. (eds). 2001. *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins, Methods of Biochemical Analysis*, vol. 43, 2nd ed., New York: John Wiley and Sons, Inc.
Gene Expression Analysis: Methods and Protocols, Raghavachari N, Garcia-Reyero, N (Eds.) 2018. ISBN 978-1-4939-7834-2, Springer
Transcriptome Data Analysis: Methods and Protocols. Wang Y, Sun, M (Eds.), 2018. ISBN 978-1-4939-7710-9; Springer
Comparative Genomics: Methods and Protocols. Setubal, J C., Stoye, Stadler P (Eds.) ISBN 978-1-4939-7463-4; Springer

- Rosenberg E. 2017. *It's in Your DNA*. 2017
- *Recombinant DNA Technology and Genetically Modified Organisms*. 2017. Nambisan P. An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology.
- He F, Zhang F, Sun W, Ning, and Wang GL. 2018. *A Versatile Vector Toolkit for Functional Analysis of Rice Genes* 11: 27.doi: 10.1186/s12284-018-0220-7.
- Kamburova VS, Nikitina EV, Shermatov SE, Buriev ZT, Kumpatla SP, Emani C and Abdurakhmonov EY. *Genome Editing in Plants: An Overview of Tools and Applications International Journal of Agronomy*. https://doi.org/10.1155/2017/7315351
- Bhardwaj R, Singh R. 2014. *Gene Silencing in Emerging Technologies and Management of Crop Stress Tolerance*, Volume 1.
- Norambuena L, Raikhel NV, Hicks GR. 2009. *Chemical genomics approaches in plant biology*. *Methods Mol Biol*. 553: 345-54. doi: 10.1007/978-1-60327-563-7_18.
- Dejonghe W and Russinova E. *Plant Chemical Genetics: From Phenotype-Based Screens to Synthetic Biology*. *Plant Physiol*. 2017 May; 174(1): 5–20.doi: 10.1104/pp.16.01805
- Fiers M, Hoogenboom J, Brunazzi A, Wennekes T, Angenent GC and Immink RGH. 2017. *A plant-based chemical genomics screen for the identification of flowering inducers*, Plant Methods 201713: 78, https://doi.org/10.1186/s13007-017-0230-2
- *Gene Overexpression in Cereals for Functional Genomics and Discovery of Useful Genes*, Abe K and Ichikawa H. 2016. *Front Plant Sci.* 7: 1359. doi: 10.3389/fpls.2016.01359
- *Gene Overexpression: Uses, Mechanisms, and Interpretation*, Prelich G. 2012. 190 no. 3 841-854; https://doi.org/10.1534/genetics.111.136911
- Wusheng Liu C. Neal Stewart Jr *Plant synthetic biology* https://doi.org/10.1016/j.tplants.2015.02.004, REVIEW| 20, 5, P309-317, 2015
- *Plant Synthetic Biology*: Quantifying the "Known Unknowns" and Discovering the "Unknown Unknowns" R. Clay Wright, Jennifer Nemhauser, 2019. DOI: https://doi.org/10.1104/pp.18.01222
- *Plant synthetic biology for molecular engineering of signalling and development*. Nemhauser JL and Torii KU. 2016. *Nat Plants* 2: 16010.doi: 10.1038/nplants.2016.10

I. Course Title : Signal Perceptions And Transduction And Regulation Of Physiological Processes

II. Course Code : PP 602*

III. Credit Hours : 2+0

IV. Why this course?

Biosignaling is emerging as an import fields in plant biology. Thorough understanding of signal perception, activation and cellular changes associated is needed for manipulation of specific traits or events in plants. The M.Sc. PhD scholar working on plant biology and related field must be exposed to this new emerging area. Plant response to external and internal factors is mainly through signal perception and amplification leading gene expression which brings in altered metabolism regulating physiological and biochemical processes and finally plant processes and growth. The course provides insights on the diverse receptors, ligand receptor interaction and the role of secondary messengers in signal amplification leading to gene expression and finally regulating plant growth.

V. Aim of the course

Objective of this course is to provide comprehensive exposure on different signaling events and associated cellular changes in plants. The course will include lectures on the signalling mechanisms employed by plants to perceive and transduce environmental signals.

The course is organized as follows:

No	Blocks	Units
1	Signal Perceptions and Transduction: Regulation of Physiological Processes	1. Concept of Receptor and Ligands 2. Receptors – Signal Perception and Transfer 3. Hormone Signaling 4. Light Signaling 5. Abiotic Stress Signaling and Nutrient Signalling 6. Signaling Cascade during Developmental Events 7. Signal Perception and Transduction in Plant Defense Responses

VI. Theory

Block 1: Signal Perceptions and Transduction: Regulation of Physiological Processes

Unit 1: Concept of Receptor and Ligands

Signal, signal types, long (diffusible) and short (contact) range signaling and components of signaling. Types of receptors, nature of ligands, downstream components like primary, secondary signaling components.

Unit 2: Receptors – Signal Perception and Transfer

Cell surface trans-membrane receptors- GPCRs, Receptor Tyrosine Kinases (RTKs), Receptors Serine Threonine kinases (RSTKs), Receptor-Like Kinases (RLKs), receptor two component systems. Signal transfer phosphor-relay and generation of secondary signaling components and activation of TFs or enzymes. Downstream components- G-proteins, second messengers-Cyclic AMP, Adenylate cyclase cascade, cyclic GMP, calcium-calmodulin-kinases; effector molecules (transcription factor).

Unit 3: Hormone Signaling

Hormone binding receptors-Transduction process. Effector molecules and gene expression. Specific signaling pathways of Auxins, Cytokinin, Gibberellins, Ethylene, ABA, Brassinosteroids, Salicylic Acid, Strigolactone, polyamines, Jasmonic acid, etc. which leads to formative effects. Cross talk in the signaling of different hormones-significance of studies with hormone action mutants.

Unit 4: Light Signaling

Perception of light-pigments involved- activation of phytochrome/cryptochrome (study of mutants). Light signal transduction. Multiple signaling cascades-identification of signaling components through mutant analysis-changes in gene expression.

Unit 5: Abiotic Stress Signaling and Nutrient Signalling

Sensing of environmental factors (Temperature-Osmotic-Ionic stress), Activation of specific molecules and secondary messengers, activation of downstream components-leading to stress gene expression, Case studies with different abiotic stresses, Retrograde signaling, Nitrogen fixation, nitrogen and phosphorus uptake, nutrient translocation.

Unit 6: Signaling Cascade during Developmental Events

Leaf senescence/fruit development and ripening, Tuberization, Sugar signaling. Signaling during seed germination.

Unit 7: Signal Perception and Transduction in Plant Defense Responses

General mechanisms to pathogen response, Role of salicylic acid and active oxygen species, Cross Talk Signaling- Stress matrix under field conditions, cross talk between abiotic-abiotic stress, biotic-abiotic stress signaling networks.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Learning outcome

By the end of this course, the student will be able to:

1. comprehendvarioussignaling events and associated physiological changes in plants.
2. understand the diverse roles of receptors, ligand receptor interaction and the role of secondary messengers in signal amplification leading to gene expression.

IX. Suggested Reading

- He, Y., Zhou, J., Shan, L. and Meng, X., 2018. *Plant cell surface receptor-mediated signaling–a common theme amid diversity*. J Cell Sci, 131(2), p.jcs209353.
- Hall, M.A., Smith, A.R., Novikova, G.V. and Moshkov, I.E., 1999. *Perception and transduction of ethylene. New Comprehensive Biochemistry*, 33, 475-490.
- Huber, A.E. and Bauerle, T.L., 2016. *Long-distance plant signaling pathways in response to multiple stressors: the gap in knowledge. Journal of Experimental Botany*, 67(7), 2063-2079.
- Pollard, T.D., Earnshaw, W.C., Lippincott-Schwartz, J. and Johnson, G., 2016. *Cell Biology* E-Book. Elsevier Health Sciences.
- Braun, Y., Smirnova, A.V., Weingart, H., Schenk, A. and Ullrich, M.S., 2007. *A temperature sensing histidine kinase—function, genetics, and membrane topology*. Methods In Enzymology: 423: 222-249. Academic Press.
- Unden, G., Wörner, S. and Monzel, C., 2016. *Cooperation of secondary transporters and sensor kinases in transmembrane signalling: the DctA/DcuS and DcuB/DcuS sensor complexes of Escherichia coli. In Advances in Microbial Physiology* (Vol. 68, 139-167). Academic Press.
- Ortiz-Urquiza, A. and Keyhani, N.O., 2016. Molecular genetics of *Beauveria bassiana* infection of insects. *Advances in Genetics* 94: 165-249). Academic Press.
- Snijders, L. and Naguib, M., 2017. *Communication in animal social networks: a missing link. Adv Study Behav*, 49, pp.297-359.

- Hedden, P. and Thomas, S.G. (eds.), 2008. *Annual Plant Reviews, Plant Hormone Signaling* 24. John Wiley and Sons.
- Eckardt, N.A., 2015. *The plant cell reviews dynamic aspects of plant hormone signaling and crosstalk*.
- Chow, B. and McCourt, P., 2006. *Plant hormone receptors: perception is everything. Genes and development,* 2015, 1998-2008.
- Leduc, N., Roman, H., Barbier, F., Péron, T., Huché-Thélier, L., Lothier, J., Demotes-Mainard, S. and Sakr, S., 2014. *Light signaling in bud outgrowth and branching in plants. Plants*, 3(2), 223-250.
- Kami, C., Lorrain, S., Hornitschek, P. and Fankhauser, C., 2010. *Light-regulated plant growth and development. Current Topics in Developmental Biology* (91: 29-66). Academic Press.
- Coureux, P.D. and Genick, U.K., 2007. *Triggering and Monitoring Light Sensing Reactions in Protein Crystals. Methods in Enzymology* (422: 305-337). Academic Press.
- Wang, C.S., Hsu, S.W. and Hsu, Y.F., 2013. *New insights into desiccation-associated gene regulation by Lilium longiflorum ASR during pollen maturation and in transgenic Arabidopsis. International Review of Cell and Molecular Biology* (301: pp. 37-94). Academic Press.
- Ben-Ari, G. and Lavi, U., 2012. *Marker-assisted selection in plant breeding. Plant Biotechnology and Agriculture* (163-184). Academic Press.
- Peleg, Z.V.I., Walia, H. and Blumwald, E. 2012. *Integrating genomics and genetics to accelerate development of drought and salinity tolerant crops. Plant Biotechnology and Agriculture* 271-286. Academic Press.
- Zhu, J.K., 2016. *Abiotic Stress Signaling and Responses in Plants*. Cell, 167(2): 313-324.
- Pandey, G.K., Pandey, A., Prasad, M. and Böhmer, M., 2016. *Abiotic stress signaling in plants: functional genomic intervention. Frontiers in Plant Science*, 7, p.681.
- Inaba, T., Yazu, F., Ito-Inaba, Y., Kakizaki, T. and Nakayama, K., 2011. *Retrograde signaling pathway from plastid to nucleus. International Review of Cell and Molecular Biology* (Vol. 290, pp. 167-204). Academic Press.
- Khan, M.I.R., Reddy, P.S., Ferrante, A. and Khan, N.A. (eds.). 2019. *Plant Signaling Molecules: Role and Regulation Under Stressful Environments*. Woodhead Publishing.
- Sparks, E., Wachsman, G. and Benfey, P.N., 2013. *Spatiotemporal signalling in plant development. Nature Reviews Genetics*. 14(9), p.631.
- Becraft, P.W., 2002. *Receptor Kinase Signaling in Plant Development. Annual Review of Cell and Developmental Biology*, 18(1) 163-192.
- Sparks, E., Wachsman, G. and Benfey, P.N. 2013. *Spatiotemporal signalling in plant development. Nature Reviews Genetics* 14(9): p.631.
- Rabellino, D., Boyd, J.E., McKinnon, M.C. and Lanius, R.A. 2019. *The Innate Alarm System: A Translational Approach. Stress: Physiology, Biochemistry, and Pathology* 197-212. Academic Press.
- Newton, A.C., Torrance, L., Holden, N., Toth, I.K., Cooke, D.E., Blok, V. and Gilroy, E.M., 2012. *Climate change and defense against pathogens in plants. Advances in Applied Microbiology* (81: 89-132). Academic Press.
- Reverchon, S., Muskhelisvili, G. and Nasser, W., 2016. *Virulence program of a bacterial plant pathogen: the Dickeya model. Progress in Molecular Biology and Translational Science* (142, 51-92). Academic Press.
- Davies, P.J. ed., 2004. *Plant Hormones: Biosynthesis, Signal Transduction, Action.* Springer Science and Business Media.
- Dzhavakhiya, V.G. and Shcherbakova, L.A., 2007. *Creation of disease-resistant plants by gene engineering. Comprehensive and Molecular Phytopathology* (439-466). Elsevier.
- Dyakov, Y.T. and Ozeretskovskaya, O.L., 2007. *Vertical pathosystem: avirulence genes and their products. Comprehensive and Molecular Phytopathology* (181-215). Elsevier.
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- Vinutha, T., Gupta, O.P., Prashat, G.R., Krishnan, V. and Sharma, P. 2014. *Molecular mechanism of Begomovirus evolution and plant defense response. Plant Virus–Host Interaction* (345-357). Academic Press.

General Source Information

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- Memon, A.R. and Durakovic, C., 2014. *Signal perception and transduction in plants. Periodicals of Engineering and Natural Sciences* (PEN), 2(2).
- Signal Transduction Mechanism: EduRev: https://edurev.in/studytube/Lecture-15-Signal-transduction-mechanisms/d82aff0d-53d8-4d71-a16c-185c6bdb517b_p
- Signaling and Communication in Plants, ISBN-10: 3540892273Springer; 2009 edition (March 18, 2009)
- Sopory SK Oelmuller R, Maheswari SC. 2012. (Ed) *Signal Transduction in Plants: Current Advances*; ISBN-13: 9781461355182
- Wang XY, Springer, 2016. *Plant Signalling Networks: Methods and Protocols* ISBN-13: 9781493961696
- *Developmental and Cell Biology Series: Hormones, Signals and Target Cells in Plant Development Series* Number 41, Osborne DJ, McManus MT, Cambridge University Press, ISBN-13: 9780521330763
- *How Plants Communicate* Machajewski S. 2018, Rosen Education Service, ISBN-13: 9781538301852
- *Signal Transduction in* Plants Aducci P (Ed), 2011, ISBN-13: 9783034899383
- *Reactive Oxygen Species: Signaling Between Hierarchical Levels in Plants.* Schmitt FJ. Allakhverdiev SI (Eds), 2017, Wiley-Scrivener ISBN-13: 9781119184881
- *Biocommunication: Sign-Mediated Interactions Between Cells and Organisms* Gordon R and Seckbach J (Ed). 2017. World Scientific Publishing Europe Ltd ISBN-13: 9781786340443
- *Annual Plant Reviews: Intracellular Signaling in Plants* Hedden P, Napier R, Yang Z (Ed) 2008, Wiley-Blackwell (an imprint of John Wiley and Sons Ltd) ISBN-13: 9781405160025

I. Course Title : Molecular Approaches for Improving Physiological Mechanisms through Trait Introgression

II. Course Code : PP 603

III. Credit Hours : 2+1

IV. Why this Course?

Phenomenal progress in understanding the basic physiological mechanisms that determine crop performance has been made in recent years. Extensive deciphering of the molecular and genetic basis of variations in these mechanisms has led to the enumeration of several "physiological traits" that have enormous relevance to improve yield potentials as well as adaptation to various biotic and abiotic stresses. Although most of the physiological traits have been considered as complex and hard to breed, recent advances in understanding the sub-components of most of the major mechanisms coupled with the progress made in "phenotyping" to capture genetic variability in such subcomponent traits have paved way for the adoption of "trait based breeding" approaches. The tremendous progresses made in genomics have also led to the development of extensive molecular and genetic resources that can be used for a focused "breeding by design".

V. Aim of the course

Deep understanding of modern translational research methods such as molecular

breeding, transgenics, genome editing, grafting and reverse breeding approaches such as Doubled haploidization will be provided to the students. Contemporary developments in molecular approaches in accelerated crop improvement would be dealt with. Acquainting with the approaches and techniques is crucial for young students to groom themselves into focused and successful scientists in future. Theoretical and practical concepts of trait introgression (or trait pyramiding) will be discussed in this course so as to provide recent developments in this area of research. To acquaint with regulatory aspects of working with transgenic plants is crucial and will be discussed elaborately.
The course is organized as follows:

No.	Blocks	Units
1.	Trait Introgression through Molecular Breeding	1. Physiological Traits Relevant for Crop Improvement and their Phenotyping 2. Identification of QTL by Bi-parental Mapping Approach 3. Identification of QTLs by Association Mapping Approach 4. Trait Introgression by Molecular Breeding Approaches
2.	Trait Introgression through Transgenic Technology	1. Gene Discovery and Gene Constructs for Relevant Plant Traits/Adaptive Mechanisms 2. Trait Improvement or Pyramiding through Transgenic Technology 3. Genome Editing, a Potential Option for Gene Regulation by Transgenic Approach 4. Characterization of Transformed Plants and Event Selection Strategies
3.	Other Approaches for Trait Introgression	1. Trait Introgression through Tissue Grafting and Asexual Propagation 2. Doubled haploids for Trait Introgression

VI. Theory

Block 1: Trait Introgression through Molecular Breeding

Unit 1: Physiological Traits Relevant for Crop Improvement and their Phenotyping

Physiological traits with relevance to growth, development, biotic/abiotic stress tolerance, nutrient acquisition, Concept of complex, multi-gene control of physiological traits, Concepts of trait introgression to augment crop productivity and/or stress adaptation.

Unit 2: Identification of QTL by Bi-parental Mapping Approach

Concepts of developing trait-specific mapping population and identification of contrasting parental lines through phenotyping, Mapping populations and their developments – F_2, RIL, doubled haploid populations, Accurate phenotyping of bi-parental mapping populations, Conventional Genotyping strategies using SNP and SSR markers, other rapid approaches like GBS, RADseq, QTLseq etc., Composite interval mapping and other approaches for QTL discovery.

Unit 3: Identification of QTLs by Association Mapping Approach

Concepts of assembling a “Panel” of germplasm amenable for association mapping based on molecular and phenotypic diversity, Concepts of linkage disequilibrium, LD decay and population structure, Concepts QTL discovery in structured populations. Phenotyping of the association mapping populations, Concepts of Genome wide association studies (GWAS).

Unit 4: Trait Introgression by Molecular Breeding Approaches

Strategies for QTL introgression and Marker Assisted Selection (MAS), Various breeding methods for trait introgression: Marker assisted backcross breeding (MABC), Marker assisted recurrent selection (MARS), Marker assisted phenotypic selection (MAPS), etc.

Block 2: Trait Introgression through Transgenic Technology

Unit 1: Gene Discovery and Gene Constructs for Relevant Plant Traits/ Adaptive Mechanisms

Map-based cloning to identify novel genes and their allelic variants, Identification of differentially expressed genes through transcriptome, metabolome and proteome analysis in contrasting genotypes, Gene identification through forward (inducing mutations with radiation, chemicals, or insertional mutagenesis)and reverse genetic approaches (site-directed mutagenesis, gene knockout or knockdown), Cloning full-length candidate genes, inducible promoters, Concepts of “codon optimization” to make constructs for specific crops.

Unit 2: Trait Improvement or Pyramiding through Transgenic Technology

Introduction to GMOs and its application in crop improvement, Gene stacking strategies for trait improvement, *Agrobacterium* and other methods of plant transformation including gene gun, *in planta*, etc.

Unit 3: Genome Editing, a Potential Option for Gene Regulation by Transgenic Approach

Genome editing techniques: CRISPR/Cas9, Zinc finger nucleases, etc, CRISPR as tool to generate loss-of-function and gain-of-function transgenics.

Unit 4: Characterization of Transformed Plants and Event Selection Strategies

Molecular analysis bySouthern, qRT-PCR/Northern analysis, and immunoassays, Concepts of copy number and desirable number of independent events, Evaluation of transgenics based on empirical/physiological/biochemical processes under specific conditions – containment and confined field trials, Generation of T1 populations, event characterization, Molecular data as per regulatory requirements, Biosafety and Regulatory aspects of GMO.

Block 3: Other Approaches for Trait Introgression

Unit 1: Trait Introgression through Tissue Grafting and Asexual Propagation

Concept of identifying root stocks with superior traits, grafting, scion root stock interaction, compatibility, concept of chimeric grafting in transgenic technology involving a non-transgenic shoot to a transgenic root.

Unit 2: Doubled haploids for Trait Introgression

Concept of crossing trait donor lines and developing doubled haploids from the F1 anthers, Screening and identifying trait introgressed doubled haploids.

VII. Practicals

- Phenotyping approaches for the different physiological traits. Development of SSR, SNP and SCAR markers, resolution of polymorphism on agarose gels and PAGE, genotyping options for SSR markers using capillary and chip based fragment analysis systems. scoring of gels and assessment of polymorphism
- Statistical approaches to assess genetic variability, heritability and other parameters. Phylogenetic analysis and principle component analysis and construction of dendrograms. Construction of Linkage map, QTL maps, population structure, LD decay etc leading to identification of QTLs.
- Bioinformatics – sequence analysis, structure analysis, designing primers for SSR regions, SNP2CAPS approaches of genotyping.
- Molecular biology - genomic/plasmid DNA isolation, RNA isolation. Full-length gene cloning, vector construction with specific promoter, gene stacking and transient assays. Transformation in model system
- Crop transformation - *Agrobacterium* mediated transformation (in-planta and invitro), particle-gun transformation.
- Evaluation of transgenics – semiquantitative and quantitative RT-PCR, southern blot, northern blot, western blot and ELISA, biochemical/physiological assay based on the function of gene and testing LOD.
- Improvement of traits based on grafting options.
- Techniques in developing doubled haploids and characterization.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

1. comprehend the basic concepts of modern translational research methods such as molecular breeding, transgenics, genome editing, grafting etc.
2. describe reverse breeding approaches such as doubled haploidization
3. accumulate both theoretical and practical concepts of trait introgression

X. Suggested Reading

Reynolds MP. 2012. *Physiological Breeding I: Interdisciplinary Approaches to Improve Crop Adaptation* Chapters 2, 3, 5: 153

Reynolds M and Langridge P. 2016. *Physiological Breeding*. Current Opinion in Plant Biology, 31: 162–17.1

Sheshshayee MS, Preethi NV, Rohini S, Sowmya HR, Smitharani A, Pooja B, Prathibha MD and Soolanayakanahally R. 2018. *Introgression of Physiological Traits for a Comprehensive Improvement of Drought Adaptation in Crop Plants. Front. Chem.*, 10.

Cossani M and Reynolds M. 2012. *Physiological Traits for Improving Heat Tolerance in Wheat. Plant Physiology*, Vol. **160**: 1710–1718

Payne T, Reynolds M and Skovmand B. *Searching genetic resources for useful variation in physiological traits* Chapter 5. *Physiological Breeding* I: Interdisciplinary Approaches to Improve Crop Adaptation Reynolds, M.P. (ed).

Bonnett D. *Optimizing marker-assisted selection (MAS) strategies for crop improvement*. Chapter 14: 153 Physiological Breeding I: Interdisciplinary Approaches to Improve Crop Adaptation Reynolds, M.P. (ed).

- Breeding Rice for Drought-Prone Environments Edited by K.S. Fischer, R. Lafitte, S. Fukai, G. Atlin, and B. Hardy. 2003, IRRI. Section 4. What molecular tools are available for selection for drought tolerance?
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- Nguyen KL, Grondin A, Courtois B and Gantet P. 2019. *Next-Generation Sequencing Accelerates Crop Gene Discovery*. *Trends in Plant Science* Vol. 24, No. 3
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- Myles S, Peiffer J, Brown PJ, Ersoz ES, Zhang Z, Costich DE and Buckler ES. 2009. *Association mapping: critical considerations shift from genotyping to experimental design. The Plant Cell*, 21(8), 2194-2202.
- Xu, Yunbi, and Crouch JH. 2008. *Marker-assisted selection in plant breeding: from publications to practice. Crop Science.* JK. 2008. 48.2 391-407.
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- Assefa T, Mahama AA, Brown AV, Cannon EK, Rubyogo JC, Rao IM and Cannon SB. 2019. *A review of breeding objectives, genomic resources, and marker-assisted methods in common bean* (Phaseolus vulgaris L.). *Molecular Breeding*, 39(2), 20.
- Rapp M, Sieber A, Kazman E, Leiser WL, Würschum T and Longin CFH. 2019. *Evaluation of the genetic architecture and the potential of genomics-assisted breeding of quality traits in two large panels of durum wheat. Theoretical and Applied Genetics*. 1-14.
- Arya KV and Shylaraj KS. 2019. *Introgression of Sub1 QTL (Submergence tolerant QTL) into the elite rice variety Jaya by Marker Assisted Backcross Breeding. Journal of Tropical Agriculture* 56(2).
- Anyaoha CO, Fofana M, Gracen V, Tongoona P and Mande S. 2019. *Introgression of Two Drought QTLs into FUNAABOR-2 Early Generation Backcross Progenies Under Drought Stress at Reproductive Stage. Rice Science*, 26(1), 32-41.
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- Thomas G, Gersbach CA and Barbas CF III. 2013. *ZFN, TALEN, and CRISPR/Cas-based methods for genome engineering. Trends in biotechnology* 31 (7) : 397-405.
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- Wei C and Wang PH. 2019. Molecular Analysis for Characterizing Transgenic Events. *Transgenic Plants,* 397-410. Humana Press, New York, NY.
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I. Course Title : Plant Phenomics-next Generation Phenomics Platforms

II. Course Code : PP 604

III. Credit Hours : 2+0

IV. Why this course?

Crop improvement in the present scenario is increasing focusing on trait based breeding. The phenomenal progress made in genomics cannot be exploited for improving plant traits/mechanisms unless phenotyping technologies are developed to capture genetic variability. Several technologies have been developed to accurately quantify genetic variability in specific traits.

V. Aim of the course

The course aims at providing cutting edge knowledge on the current progress made in various phenotyping techniques and approaches. The students will be versed with principles of various phenotyping approaches. The aim is to provide hands-on expertise in analyzing trait diversity. Exposure will be provided on Non-invasive imaging technologies that drive the phenomics platforms. The course provides comprehensive exposure on recent developments in phenomics platforms imaging tools/techniques and recent trends in designing specific phenomics platforms e.g. drought studies/root phenotyping etc.

The course is organized as follows:

No	Blocks	Units
1.	Concepts of High throughput Phenotyping and its Requirement	1. Concepts of Phenotyping 2. Physio-Morphological Traits Associated with Crop Performance 3. Features of Phenomic Platforms 4. Trends in Phenomics 5. Non-invasive Phenotyping Approaches
2.	Applications of the Phenomics Platforms	1. Basic Studies to Assess the Crop Response 2. Applied Studies Focused on Crop Improvement Programs

VU, Theory

Block 1: Concepts of High throughput Phenotyping and its Requirement

Unit 1: Concepts of Phenotyping

The concepts of "phene and trait" analogous to gene and allele. Genome-phenome relationship, definition of phenotyping, GxE interaction on phenome.

Unit 2: Physio-Morphological Traits Associated with Crop Performance

Overview of phenotyping needs to complement genomic resources, specific traits associated with yield potential, stress adaptation (both biotic and abiotic stresses). Need for high throughput precision phenotyping approaches for basic studies and to generate genetic and genomic resources.

Unit 3: Features of Phenomic Platforms

Precision growth conditions, maintenance of light, temperature/VPD and RH to realize the potential crop growth response, Controlled environmental facilities for simulating challenging climatic conditions to phenotype diverse plant traits, Concept of sensors, diverse sensors and their utility in precise quantification of environmental variables, soil moisture sensors, Imaging to capture plant traits, image acquisition. Automated big data access, processing, etc.

Unit 4: Trends in Phenomics

Types of phenomic platforms- Laboratory, Greenhouse and the field-based platforms. Platforms designed for specific needs i.e., root phenotyping, drought studies etc., Crop specific phenotyping, mobile and stationary platforms, Global trends in establishing major phenomics platforms, and their characteristic features and impact.

Unit 5: Non-invasive Phenotyping Approaches

The concept of non-invasive capturing of plant growth and health, Imaging technologies - image acquisition, segmentation and data analysis, Critical aspects of Visual, IR Thermal, Fluorescence, NIR, Hyperspectral imaging, Development and validation of models for deriving relevant physiological traits from image phenome. Concepts of Plants to sensors and sensors to plants, Stationary and ground based tractor mounted sensors/imaging tools, Unmanned aerial vehicle (UAV) sensors, Machine learning and its integration to analyze ground and aerial based images.

Block 2: Applications of the Phenomics Platforms

Unit 1: Basic Studies to Assess the Crop Response

Functional validation of genes, chemicals and other interventions, Characterize the growth and stress response in contrasts to identify the relevance of adaptive trait.

Unit 2: Applied Studies Focused on Crop Improvement Programs

Characterizing the pre-released promising lines for productivity under defined environmental variables. Phenotyping germplasm accessions, mapping populations for specific traits for mapping, Concept of Phenome Wide Association Studies (PWAS). Genomic selection, gene-based crop models to predict complex traits, Impact of phenomics platform, progress made, case studies.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Learning outcome

By the end of this course, the student will be able to understand the current progress made in various phenotyping techniques and approaches.

IX. Suggested Reading

- Pieruschka R and Poorter H. 2012. *Phenotyping plants: genes, phenes and machines. Functional Plant Biology*, 39(11), 813-820.
- Noah F, Gehan MA and Baxter I. 2015. *Lights, camera, action: high-throughput plant phenotyping is ready for a close-up. Current Opinion in Plant Biology* 24 2015: 93-99.
- Singh AK, Ganapathysubramanian B, Sarkar S and Singh A. 2018. *Deep learning for plant stress phenotyping: trends and future perspectives. Trends in Plant Science.*
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- Lyu JI, Baek SH, Jung S, Chu H, Nam HG, Kim J and Lim PO. 2017. *High-throughput and computational study of leaf senescence through a phenomic approach. Frontiers in plant science,* 8, 250.
- Jeudy C, Adrian M, Baussard C, Bernard C, Bernaud E, Bourion V and Lamboeuf M. 2016. *RhizoTubes as a new tool for high throughput imaging of plant root development and architecture: test, comparison with pot grown plants and validation. Plant Methods*, 12(1), 31.
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- Costa C, Schurr U, Loreto F, Menesatti P and Carpentier S. 2018. *Plant Phenotyping Research Trends, a Science Mapping Approach. Frontiers in Plant Science*, 9.
- Das Choudhury S, Samal A and Awada T. 2019. *Leveraging Image Analysis for High-Throughput Plant Phenotyping. Frontiers in Plant Science*, 10, 508.
- Golzarian MR, Frick RA, Rajendran K, Berger B, Roy S, Tester M and Lun DS. 2011. *Accurate inference of shoot biomass from high-throughput images of cereal plants. Plant Methods*, 7(1), 2.
  https://www.fz-juelich.de/ibg/ibg-2/EN/methods_jppc/methods_node.html
- Hartmann A, Czauderna T, Hoffmann R, Stein N and Schreiber F. 2011. *HTPheno: an image analysis pipeline for high-throughput plant phenotyping. BMC bioinformatics*, 12(1), 148.
- Berger B, Parent B and Tester M. 2010. *High-throughput shoot imaging to study drought responses. Journal of Experimental Botany*, 61(13), 3519-3528.
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- DominguesFranceschini M, Bartholomeus H, van Apeldoorn D, Suomalainen J and Kooistra L. 2017. *Intercomparison of unmanned aerial vehicle and ground-based narrow band spectrometers applied to crop trait monitoring in organic potato production*. Sensors, 17(6), 1428.
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- Parent B, Shahinnia F, Maphosa L, Berger B, Rabie H, Chalmers K and Fleury D. 2015. *Combining field performance with controlled environment plant imaging to identify the genetic control of growth and transpiration underlying yield response to water-deficit stress in wheat. Journal of Experimental Botany* 66(18): 5481-5492.
- Araus JL and Cairns JE. 2014. *Field high-throughput phenotyping: the new crop breeding frontier. Trends in Plant Science* 19(1): 52-61.
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- Rahaman M, Chen D, Gillani Z, Klukas C and Chen M. 2015. *Advanced phenotyping and phenotype data analysis for the study of plant growth and development. Frontiers in Plant Science*. 6, 619.
- Campbell ZC, Acosta-Gamboa LM, Nepal N and Lorence A. 2018. *Engineering plants for tomorrow: how high-throughput phenotyping is contributing to the development of better crops. Phytochemistry Reviews*. 17(6), 1329-1343.
- Araus JL, Kefauver SC, Zaman-Allah M, Olsen MS and Cairns JE. 2018. *Translating high-throughput phenotyping into genetic gain. Trends in Plant Science* 23(5): 451-466.

General Source Information

- Montes JM, Melchinger AE and Reif JC. 2007. *Novel throughput phenotyping platforms in plant genetic studies. Trends in Plant Science*, 12(10): 433-436.
- Development of high throughput plant phenotyping facilities at aberystwyth (ppt)
- Zhou J, Reynolds D, Websdale D, Le Cornu T, Gonzalez-Navarro O, Lister C and Clark M. 2017. *CropQuant: An automated and scalable field phenotyping platform for crop monitoring and trait measurements to facilitate breeding and digital agriculture*. BioRxiv, 161547.
- Bradshaw JE. 2017. *Plant breeding: past, present and future. Euphytica*, 213(3), 60.
- Lee U, Chang S, Putra GA, Kim H and Kim DH. 2018. *An automated, high-throughput plant phenotyping system using machine learning-based plant segmentation and image analysis. PloS one*, 13(4), e0196615.
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I. Course Title : Experimental Techniques to Characterize Plant Processes for Crop Improvement

II. Course Code : PP 605

III. Credit Hours : 0+2

IV. Why this Course?

Techniques, tools and instrumentation facilities drive the research in modern biology. The course addresses recent developments related to advanced quantification methods based on novel methodologies and instruments. Besides the emphasis is on new emerging trends in assessing physiological and biochemical processes based on surrogate methods. Several molecular biology techniques are now essential to comprehend physiological processes. The course provide comprehensive picture on these areas addressing recent developments in this area.

V. Aim of the course

Aim of this course is to provide exposure to phenotype very specific physiological processes which have direct relevance in crop improvement programmes. The course provides insight on recent techniques and methodologies on each of the major physiological processes like stress responses, photosynthetic process, hormone area, photo-morphogenesis and genomics aspects.

The course is organized as follows:

No.	Blocks	Units
1.	Characterization of Plant Processes: Experimental Techniques and Crop Improvement	1. Stress Responses 2. Photosynthetic processes 3. Hormonal Response on Specific Plant Growth Processes and Quantification 4. Nutrient Response Acquisition and Quantification 5. Photo and Thermo Morphogenesis 6. Recent Approaches for Functional Genomics

VI. Theory

Block 1: Characterization of Plant Processes: Experimental Techniques and Crop Improvement

Unit 1: Stress Responses

Thermal (reflectance) characters as a measure of water status and root characteristics, Oxidative stress induction and assessing the response on lipid peroxidation and quantification of ROS, RCC's, RNS, Fluorescence to assess the stress response, Water use efficiency quantification at leaf, plant level, surrogates for WUE, Tissue localization of ROS, RNS by qualitative staining and fluorescence-based methods.

Unit 2: Photosynthetic processes

Concept and approaches to assess of radiation utilization efficiency (RUE), Quantification of mesophyll and other diffusive resistances regulating photosynthesis. Carboxylation efficiency (light and CO_2 response curves), RuBiSCO activation status

Unit 3: Hormonal Response on Specific Plant Growth Processes and Quantification

Bioassays to assess the biological process regulated by hormones – new in-vivo assays, Promoter assays for hormone response- GUS/YFP/GFP based assays-expression of hormone responsive genes, Recent analytical tools and techniques to quantify hormones – GC-MS, LC-MS, Capillary electrophoresis.

Unit 4: Nutrient Response Acquisition and Quantification

Recent advances in soil less cultures to study the nutrient response- Hydroponics/

Aeroponics/Fogoponics, Noninvasive techniques to quantify nutrients – XRD (X-Ray Diffraction analysis) and hyper spectral reflectance.

Unit 5: Photo and Thermo Morphogenesis

Photo receptors, light and temperature regulation of plant growth and flowering, Thermal time, heat units, GDD, Concept and approaches for speed breeding.

Unit 6: Recent Approaches for Functional Genomics

In silico prediction of gene function, Flanking sequence identification in insertional (T-DNA/transposon) mutants, Concept of insertional mutagenesis and mutant experiments, Utilization of genetic resources for functional genomics – mutants and tilling, eco tilling, VIGS, RNAi, miRNA, Genome editing –CRISPR, Concept of chemical genomics for functional validation, Relevant molecular tools to assess gene expression or (to regulate the process and assign a function to gene), Multiple gene expression by Nano String technology, Cap analysis gene expression (CAGE) – to identify start point of transcription, Yeast hybrid interaction, Immunoprecipitation, Chip-PCR.

VII. Teaching methods/activities

– Practical Assignments
– Results presentation

VIII. Learning outcome

After completion of this course students are expected to develop practical skill and knowledge on various experimental techniques employed in crop improvement programme. Moreover, students will have experience with characterization of plant processes.

IX. Suggested Reading

- Costa, Miguel and Grant, Olga and Chaves M. 2013. *Thermography to explore plant-environment interactions. Journal of Experimental Botany* **64**. 10.1093/jxb/ert029.
- Padhi Jyotiprakash and K Misra R and Payero Jose. 2009. *Use of infrared thermography to detect water deficit response in an irrigated cotton crop*.
- Root Phenotyping for Drought Tolerance: A Review, Wasaya A, Zhang X, Fang Q and Yan Z. 2018. *Agronomy* 8, 241; doi: 10.3390/agronomy8110241
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Horticulture other than Soils In Situ 126 435-448.
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- Alonso JM, Stepanova AN. 2015 (Eds.) *Plant Functional Genomics, Methods and Protocols*
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- Shan Q, Wang Y, Li J, Yi Z, Chen K, Liang Z, Zhang K *et al*. 2013. *Targeted genome modification of crop plants using a CRISPR-Cas system. Nature Biotechnology* 31 (8): 686.
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I. Course Title : Global Climate Change and Crop Response

II. Course Code : PP 606

III. Credit Hours : 2+0

IV. Why this Course?

Present Indian agriculture encounters tremendous challenges due to rapid climate change. Climate change exerts remarkable negative impact on food, nutritional and ecological security. It significantly affects the plant physiological processes, hence yield is severely affected. Therefore students of plant physiology need to quip themselves with knowledge and skill sets required to navigate the climate change scenario and its impact on crops physiological processes. Hence, this course is designed .

V. Aim of the Course

The course is designed to provide basic knowledge on the subjects of crop responses to climate change. The aim of this course is to address both long-term and short-term effects of climate change on crops, natural vegetations and ecosystems.

The course is organized as follows:

No.	Blocks	Units
1.	Climate Change: Crop Response and Mitigation	1. Fundamentals of Climate Change 2. Manifestations of Climate Change 3. Major GHGs (CO_2, Methane, NO_2 etc.), their Production Rates, Monitoring and their Influence on Climate Change 4. Agricultural Practices on GHG Production 5. Direct and Indirect Effects of Climate Change on Plant Processes 6. Climate Change Scenario and Impact on Crops 7. Ozone Depletion leading to Increased Ionizing Radiations and its Implications on Crop Growth 8. Long-term and Short-term Projections of Climate Change: Effects on Natural Vegetation and Ecosystems 9. Technologies for Climate Change Mitigation in Agriculture 10. Climate-resilient Agriculture 11. Climate Change: Technologies for Crop Response Studies 12. Politics of Climate Change Negotiations

VI. Theory

Block 1: Climate Change: Crop Response and Mitigation

Unit 1: Fundamentals of Climate Change

Definition of climate change, history and evidences of climate change and its implications. Natural and anthropogenic climate change. Sources of Greenhouse Gas (GHG) emission, Global Warming Potential of GHGs, accumulation of GHGs in the atmosphere and science behind climate change, industrial revolution and GHG build-up in the atmosphere, Energy-Emission-Economy Interactions, carbon intensity of economy, carbon equity/justice.

Unit 2: Manifestations of Climate Change

Impact on monsoons, occurrence of extreme weather events, hydrological cycle and water availability, effect on crop growing period in tropics, subtropics and temperate regions, shifts in distribution of flora and fauna, effects on biodiversity and migration of tropical plant species to higher latitudes and altitudes.

Unit 3: Major GHGs (CO_2, Methane, NO_2, etc.), their Production Rates, Monitoring and their Influence on Climate Change

GHGs: An Overview, - role of CO_2, methane and major uncertainties. Mechanism of their production and emission from various, source and sinks of GHGs; and contribution of GHGs to global warming. Techniques used in monitoring GHGs.

Unit 4: Agricultural Practices on GHG Production

Carbon footprint analysis of agriculture and various agricultural practices contribute to climate change. Impacts of natural factors and farming practices on greenhouse gas emissions. Sources of agricultural GHG emission- Agricultural Soil Management, enteric fermentation, manure management, other sources. Opportunities to reduce GHG emission from Agriculture.

Unit 5: Direct and Indirect Effects of Climate Change on Plant Processes

Problems and Prospects of Crops with changing temperature: Growth and Development of Crop plants, Thermo-morphogenesis, phenology, Physiological processes such as photosynthesis, Net carbon assimilation, C_3 and C_4 plants adaptation,Respiration, Nutrient acquisition and metabolisms, Plant water relations and Heat shock proteins, Grain/seed development: Grain Quality parameters and yield.

Unit 6: Climate Change Scenario and Impact on Crops

Different scenarios for temperature, rainfall in different agro-climatic zones of India and their impact on crop growth and productivity. Major climate change (temperature, CO_2, and rainfall) impact quantification using field or controlled environment experiments, meta-analysis and simulation models. Some examples of crop simulation models calibration and their application in short-term and long-term predictions.

Unit 7: Ozone Depletion leading to Increased Ionizing Radiations and its Implications on Crop Growth

Role of CFCs in ozone depletion, penetration of ionizing UV radiations and its implications on crop growth.

Unit 8: Long-term and Short-term Projections of Climate Change: Effects on Natural Vegetation and Ecosystems

Response of natural ecosystems to increasingatmospheric CO_2 concentration and climate warming, effect of climate change on quality of feed i.e leaf and stored grains/seeds, its implications on pollinators and pests

Unit 9: Technologies for Climate Change Mitigation in Agriculture

Agricultural biotechnology to produce crop varieties with enhanced carbon uptake.
Nutrient management: Management of nitrogenous fertilizers.
Tillage/residue management: 1.Conservation tillage CO_2 mitigation technology; 2. Biochar: A potentialtechnique for carbon sequestration.
Methane mitigation using reduced tillage technology, change in methanogenic bacterial activity using electron acceptors.
Carbon sequestration potential, concept and measurement.

Unit 10: Climate-resilient Agriculture

Conventional and biotechnological approaches to improve the crop adaptation to climate change. Relevance of "Genome wide mutants" to identify genes/processes for improved adaptation to changing environments.

Unit 11: Climate Change: Technologies for Crop response studies

Temperature Gradient Chambers, Temperature Gradient Greenhouses, Soil plant atmosphere research system (SPAR), Infra-red warming Technology, Free Air temperature enrichment technology, Soil Warming system etc.

Unit 12: Politics of Climate Change Negotiations

IPCC, Major International conventions/treaties, Kyoto Protocol, Paris Agreement, Global initiatives on Carbon sequestration, carbon trading.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Learning outcome

After completion this course, students will be able to obtain in depth and basis knowledge on crop responses to climate change.

IX. Suggested Reading

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- IPCC AR5 Reports WG I 2013
- IPCC AR5 Reports WG II and III 2014
- IPCC Special Reports
- UNFCCC website
- IPCC website
- NOAA website
- CCAFS website
- India's Second National Communication to UNFCCC

- INCCA Report, MoEF and CC
- MoEF and CC website

I. Course Title : Physiological and Molecular Aspects of Source-sink Capacity for Enhancing Yield

II. Course Code : PP 607*

III. Credit Hours : 3+0

IV. Why this course?

Yield level reached plateau in many crops improving yield potential and crop growth rate forms the basis for further improvement in productivity. Photosynthesis and the establishing sink capacity are crucial processes to achieve this goal. Very good progress has been made in deciphering the molecular mechanisms to regulate several photosynthetic processes at cellular and canopy level. Similar insights now exist regarding establishing sink size (capacity). In the last five years, phenomenal conceptual approaches have been developed to understand the basic physiological and molecular mechanisms to enhance the source through photosynthetic processes. Besides, scientific insights in recent years provided leads in improving sink ie., yield associated traits. Yield plateau can be broken only by enhancing yield potential by structured improvement in source capacity and sink size.

V. Aim of the course

The course addresses the recent development in photosynthetic processes that can be exploited to improve yield potential. Besides, other major emphasis is to provide exposure on recent developments in regulating the sink characters ie., yield attributes at molecular level to achieve higher potential yields.

The course is organized as follows:

No.	Blocks	Units
1.	Source Size and Function- Basic Concepts, Physiological and Molecular Mechanisms, Genomic RESOURCES to Regulate Source Characters	1. Source Establishment 2. Source Function- Photochemical Reactions 3. Source Function- CO_2 Diffusion and Concentration 4. Source Function- Metabolic Engineering of CO_2 Fixation 5. Case Studies to Improve Source Capacity
2.	Improving Sink Size and Capacity	1. Sink Establishment 2. Increase the Sink Size by Enhancing the Relevant Constituent Traits 3. Genetic Genomic RESOURCES, Genes/QTLs, Genetic RESOURCES to Improve Sink Traits– Case Studies 4. Source to Support the Sink Capacity

VI. Theory

Block 1: Source Size and Function–Basic Concepts, Physiological and Molecular Mechanisms, Genomic Resources to Regulate Source Characters

Unit 1: Source Establishment

Maximize energy capture by improved light interception, light distribution and its utilization efficiency, concepts of shade avoidance response (SAR) and option to increase, Increase canopy size by vertical expansion – concept of increasing optimum LAI levels, Concepts of semi-tall varieties with resistance to lodging: traits associated with lodging resistance, Sustain net carbon gain with age – the relevance of stay green character, photon capture and achieve high CO_2 reduction to photon ratio under low light, Options for increasing canopy photosynthesis, Relevance of maintaining cell turgor and nutrient status.

Unit 2: Source Function- Photochemical Reactions

Maximize conversion efficiency of intercepted radiation by improving net carbon gain - Emerging solutions to increase carbon fixation rate, Improve efficiency of photochemical reaction by - Engineering the pigments to expand PAR spectrum into IR range; reduce antenna size, optimize energy dissipation mechanisms; optimize components of ETC and downstream acceptors; accelerate adaptation for shifting light intensities.

Unit 3: Source Function- CO_2 Diffusion and Concentration

Enhance stomatal conductance (g_s) and mesophyll conductance (g_m) – guard cell metabolism; concepts of leaf mesophyll tissue thickness (SLW), Concepts of VPD responses of g_s to enhance duration of photosynthesis during the day, Bicarbonate transports and aquaporins; achieve higher CCM - Engineering C4 cycle, CAM, cyanobacteria, carboxysomes, algal pyrenoids.

Unit 4: Source Function- Metabolic Engineering of CO_2 Fixation

RuBisCO carbon fixation activity - Increase and optimize kinetics of RuBisCO with enhanced specificity to CO_2, Engineer RuBisCO to minimize feedback regulation by metabolite inhibitors, Increased activation state by improving stability and function of RuBisCOactivase; optimize RuBp regeneration – modulate specific enzyme levels. New concepts on photorespiratory synthetic bypass.

Unit 5: Case Studies to Improve Source Capacity

Genetic and genomic resources, genes/QTLs associated with specific yield potential traits and/or photosynthetic mechanisms, Genetic resources to improve source traits-case studies.

Block 2: Improving Sink Size and Capacity

Unit 1: Sink Establishment

Optimise duration of phenological stages related to sink establishment, genetic and environmental factors, GDD and phenology.

Unit 2: Increase the Sink Size by Enhancing the Relevant Constituent Traits

Role of hormones in regulating molecular mechanisms of yield structure development, Genomic and genetic resources developed for regulation/improvement of such traits. – Sink Size: Tillering associated traits, branching patterns/fruiting points, spikelet number, pod number, fruit number. – Sink development: Basic concepts and molecular mechanisms associated with pollination, fertilization, ovary development in determining the spikelet fertility/sterility components and strategies for engineering seed/fruit size in crop plants.

Unit 3: Genetic and Genomic Resources, Genes/ QTLs, Genetic Resources to Improve

Sink Traits- Case Studies. Progress and status in developing genomic and genetic resources of validated genes/ QTLs to improve sink traits- Specific case studies.

Unit 4: Source to Support the Sink Capacity

Canopy architecture to support sink requirements in cereals: plant height, tillering, leaf area, shading or senescence of lower canopy leaves, canopy photosynthesis, Canopy architecture to support sink requirements in Pulses: Leaf senescence, abscission, mobilization of N and other nutrients, Symbiotic N fixation to support sink size and capacity in pulses.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Learning outcome

By the end of this course, the student will be able to:

1. comprehend the current development in photosynthetic research
2. know how to employ the theoretical concept of photosynthetic research in yield improvement programme
3. understand the mechanisms of source and sink establishment

IX. Suggested Reading

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- Christophera M, Chenub NK, Jenningsa R, Fletchera S, Butlera D, Borrellc A, Christopher J. 2018. *QTL for stay-green traits in wheat in well-watered and water-limited environments. Field Crops Research* 217 (2018) 32–44
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I. Course Title : Seed and Fruit Growth and their Quality Improvement

II. Course Code : PP 608

III. Credit Hours : 2+0

IV. Why this Course?

Seed as a propagule is an important input for agriculture. From this context, aspects related to seed development, its dormancy and viability etc. assumes significance. Besides, seed is the major source of nutrition to mankind and hence, quantitative and qualitative differences in seed constituents and their modification and improvement have been the area of focus in recent years. Several molecular approaches are now being adapted to improve the seed characters like longevity, vigour and seed quality. In addition to seed and fruit development, processes regulating the post-harvest deterioration of fruits and vegetables, increasing their self-life are another area that needs comprehensive intervention involving molecular biology tools and techniques. The course therefore addresses recent developments on these aspects.

V. Aim of the course

The major aim of the course is to train and educate the students about the importance of seeds and fruits as a source of nutrition for human health. Further, this course also addresses how to improve the nutritional status besides protecting the nutritive value of seeds and fruits. In addition, the other aim of the course is to address to regulate the post harvest deterioration of seeds and fruits to minimize the losses.

The course is organized as follows:

No.	Blocks	Units
1.	Physiological and Molecular Aspects of Seed and Fruit Growth: Quality Improvement	1. Physiology of Seed Growth and Development 2. Seed as a Propagule 3. Seed as a Source of Nutrition 4. Quality Deterioration during Storage 5. Fruit Growth and Development 6. Fruit as a Source of Phytochemicals: Nutraceuticals 7. Fruit Ripening, Post Harvest Deterioration and Shelf life

VI. Theory

Block 1: Physiological and Molecular Aspects of Seed and Fruit Growth: Quality Improvement

Unit 1: Physiology of Seed Growth and Development

Mechanism of seed development and different developmental stages; synthesis, mobilization and accumulation of stored reserves, Forms of stored reserves and their localization, Sink drawing ability (SDA) and its relevance in seed growth and development, Role of plant hormones in seed growth and development and SDA.

Unit 2: Seed as a Propagule

Seed as a propagation material; seed size and seed chemical composition and their relevance in seed germination, Physiological, biochemical and molecular mechanisms and approaches to regulate seed germination, seedling emergence and establishment and seedling vigour, Physiological, biochemical and molecular mechanisms and approaches to regulate seed priming and crop establishment: seed dormancy, precocious germination and controlling pre-harvest sprouting in crops, Physiological, biochemical and molecular mechanisms and approaches to regulate seed viability, improving the viability and storability of seeds.

Unit 3: Seed as a Source of Nutrition

Seed as a source of nutrition to humans: approaches to improve the quality of seeds through synthesis of seed storage reserves and other constituents, Genes/ QTL's regulating these processes and concept of pathway engineering to improve the quantity and quality of seed constituents, Carbohydrates- Amylose and amylopectin ratios for glycemic index, resistant and digestable starch, improving dietary fibre, alter gelatinisation, Protein content, modified proteins, essential amino acids, Oil content, fatty acid composition, Omega 3 fatty acids. Carotenoids and vitamins, Biofortification strategies to enhance the grain zinc, iron, other minerals and other essential compounds, Engineering for low protease inhibitors, phytic acid, tannins, phenolic substances, lectins, oxalates as anti-nutritional factors, Case studies of improving seed nutrition components by molecular breeding and transgenic approaches.

Unit 4: Quality Deterioration during Storage

Changes in chemical composition during storage; factors influencing the deterioration of nutritional quality of seeds during storage; approaches to minimize nutritional quality deterioration, Effect of quality deterioration on human and animal health

Unit 5: Fruit Growth and Development

Flower and fruit development; concept of parthenocarpy, Physiological and biochemical changes during fruit development and chemical composition, Molecular approaches to regulate flower and fruit drop/ abscission; Role of hormones.

Unit 6: Fruit as a Source of Phytochemicals: Nutraceuticals

Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Antioxidants, Flavanoids, anthocyanins, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Vitamins- Vitamin C, Tocopherol, Carotenoids, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Alkaloids, Mangiferin, tomatins, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of DigestableFiber lycopene, stillbeans, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Aroma, monoterpenoids and Fatty acid esters.

Unit 7: Fruit Ripening, Post Harvest Deterioration and Shelf life

Physiological and molecular mechanisms of fruit ripening, Postharvest deterioration of fruits; factors regulating fruit deterioration; hormonal and environmental aspects of reducing post harvest deterioration of fruits, Physiological and Molecular approaches to regulate fruit ripening and shelf life: Role of Ethylene and Ethylene response factors regulating specific processes of fruit ripening; Approaches to regulate specific shelf life characters, Improving fruit ripening and shelf life by molecular approaches-Case studies.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

1. comprehend the importance of seeds and fruits as a source of nutrition
2. describe how to improve the nutritional status of grains and fruits
3. know how to protect the nutritive value of seeds and fruits
4. detect the post harvest deterioration of seeds and fruits and to minimize the losses

IX. Suggested Reading

- Bewley, JD, Bradford K, Hilhorst H, Nonogaki H. (2013). *Seeds: Physiology of Development, Germination and Dormancy*, Springer-Verlag
- Larkins BA and Vasil IK (Ed). 2010. *Cellular and Molecular Biology of Plant Seed Development,* Springer
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- Sperotto RA, Ricachenevsky FK, Waldow VdA, Fett JP. *Iron biofortification in rice: It's a long way to the top, Plant Science* 190 (2012) 24–39
- Lee J, Nou IS, Kim HR. 2012. *Current status in calcium biofortification of crops, J Plant Biotechnol* 39: 23–32, DOI: http://dx.doi.org/10.5010/JPB.2012.39.1.023
- Sharma D, Jamr G, Singh UM, Sood S and Kumar A. 2017. *Calcium Biofortification: Three Pronged Molecular Approaches for Dissecting Complex Trait of Calcium Nutrition in Finger Millet (Eleusine coracana) for Devising Strategies of Enrichment of Food Crops*, doi: 10.3389/fpls.2016.02028
- Gemede HF and Ratta N. 2014. *Antinutritional factors in plant foods: Potential health benefits and adverse effects. International Journal of Nutrition and Food Sciences*, 3(4), pp.284-289.
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- Kumar D and Kalita P. 2017. *Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries*. Foods, 6(1), p.8.
- Kawakatsu T, Hirose S, Yasuda H and Takaiwa F. 2010. *Reducing rice seed storage protein accumulation leads to changes in nutrient quality and storage organelle formation. Plant Physiology* 154(4), pp.1842-1854.
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- Siddiqui MW. ed., 2015. *Postharvest biology and technology of horticultural crops: principles and practices for quality maintenance*. CRC Press.
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I. Course Title : Plant-Microbe Interactions

II. Course Code : PP 609

III. Credit Hours : 2+1

IV. Why this Course?

Plant microbe encounters can be friendly or hostile. Plants are associated with a variety of microorganisms, including endophytes, phylloplane and rhizosphere microbes which provide plants with mineral nutrients and other benefits. In contrast phytopathogens obtain nutrition from plants leading to reduction in plant growth and subsequent killing. Besides the genetic makeup expression of the phenotype is regulated by environment and the plant microbe interaction especially the endophytes. It is also relevant to understand the plant-pathogen and plant-insect interactions to improve tolerance mechanisms by altering specific physiological and biochemical processes. The combined effects of biotic and abiotic are another aspects of importance. Understanding how physiology of plants simultaneously exposed to abiotic stress and pathogens decides the outcome of their interactions is important. The course provides comprehensive information on these aspects. Plant-microbe interaction is an emerging area and PhD scholar must be exposed to this new knowledge which might help in manipulation plant traits and boost crop growth.

V. Aim of the Course

The objective of the course is to provide the understanding how beneficial microbes (endophyte/rhizosphere/phylloplane microbiome) play a role in boosting the plant immune system and thereby stimulate plant health and growth. The course also aims to understand how plant pathogens are able to infect plants and how resistant plants are able to defend themselves. The course covers comprehensive interactive information from physiology, microbiology and genomics.

The course is organized as follows:

No.	Blocks	Units
1.	Plant Pathogen Interaction	1. Introduction to Plant Pathogen Interaction 2. Genetic Basis of Host Pathogen Interaction 3. Growth Regulators of Plant Defense and Susceptibility 4. Bioenergetics in Plant Pathogen Interaction
2.	Plant-Endophytes/ Rhizosphere/ Phylloplane Microbes Interaction	1. Interaction of Endophytes/ Rhizosphere/ Phylloplane Microbes with Plants 2. Role of Endophyte/ Rhizospheric/ Phylloplane Microbiota in Plant Physiological Processes 3. Endophyte/ Rhizospheric/ Phylloplane Microbes in Improving Biotic and Abiotic Stress Tolerance 4. Bioethics, Biosafety, Intellectual property rights and implications in plant-microbe research
3.	Microbial Interaction with Plants in The Presence of Abiotic Factors	1. Disease Triangle and the Contribution of the Environmental Factors in Influencing the Plant-microbe Interaction 2. Physiological and Molecular Basis for Predisposition or Endurance of Plant during Abiotic-biotic Stress Interaction

VI. Theory

Block 1: Plant Pathogen Interaction

Unit 1: Introduction to Plant Pathogen Interaction

Introduction to plant microbe interaction and importance, the concepts of holobiome and hologenome, Differences between endophytes/ rhizosphere/phylloplane microbes and phytopathogens, Types of endophytes/rhizosphere/phylloplane microbes, and their classifications

Unit 2: Genetic Basis of Host Pathogen Interaction

Genetics of immune response, Signal perception, Host-pathogen interaction (bacteria, fungus and virus), Nature of resistance to diseases-pathogenecity genes *(pat)* in plant pathogens-disease specific genes *(dsp), avirulence genes (avr), avr gene – coded proteins-structure of avr genes,* Transmission of the alarm signal to host defense producers: signal transduction, pathogen elicitors, protein kinases, calcium ions, phosphorylases, phospholipases, ATPases, Accumulation of Phytoalexins as a Resistance mechanism-Biosynthesis and metabolism of Phytoalexins, Modes of action of Phytoalexins, Pathogenesis-Related proteins (PR) and Disease Resistance- intro-Characterization and biological functions of PR proteins, Biosynthesis of PR proteins.

Unit 3: Growth Regulators of Plant Defense and Susceptibility

Regulation of hormones countering the pathogen infection and toxins modulating the plant physiology, ABA-SA cross talk and role of JA during plant interaction biotrophic and necrotrophic pathogens respectively.

Unit 4: Bioenergetics in Plant Pathogen Interaction

An overview of energy-capture and energy-utilization processes in higher plant, Energy-capture and utilization process as affected by pathogenic infection, Molecular basis of pathogenesis and the process of interaction- classical examples of pathogens causing necrosis, wilts, tumours and soft rots, Role of primary metabolism in plant-pathogen interaction.

Block 2: Plant-Endophytes/ Rhizosphere/ Phylloplane Microbes Interaction

Unit 1: Interaction of Endophytes/ Rhizosphere/ Phylloplane Microbes with Plants

Approaches to study endophytic/ rhizosphere/ phylloplane microbes bacteria and fungi, Intracellular bacteria 'Cytobacts', Possible mechanisms of host plant genotype influence in recruitment of endophytic microbes vertical/ seed transmission, Inter-kingdom signaling regulating endophyte/ rhizosphere/phylloplane microbes development, Adaptation with respect to colonization of endophytes/ rhizosphere/ phylloplane microbes.

Unit 2: Role of Endophyte/ Rhizospheric/ Phylloplane Microbiota in Plant Physiological Processes

Phytohormones role in beneficial endophyte/rhizospheric/phylloplanerecruitment, Hormonal regulation of assimilate partitioning in plant-microbe interactions, Plant-Fungus-Bacteria, the three fold interaction for improved plant nutrition.

Unit 3: Endophyte/ Rhizospheric/ Phylloplane Microbes in Improving Biotic and Abiotic Stress Tolerance

Importance in imparting stress (biotic and abiotic) adaptations, in the regulation of bioactive compound (alkamide) accumulation; acclimatization of root-interacting fungi for improved plant nutrition and stress tolerance, Cultivable versus uncultivable endophytes with respect to their extent of tissue colonization and diversity, Genetic engineering of endophytes for production of industrially important bioactive compounds, endophyte-enrichment technologies in crops for traits manipulation, Role of existing microbiome on introduced endophyte, symbiotic microbes and their interaction, Modern techniques for examining plant-microbe-insect interactions.

Unit 4: Bioethics, Biosafety, Intellectual property rights and implications in plant-microbe research

DBT biosafety regulations on working with microbial organisms associated with plants, Standard operating procedure (SOP), Committees dealing with biosafety and safe release of microorganisms.

Block 3: Microbial Interaction with Plants in the Presence of Abiotic Factors

Unit 1: Disease Triangle and the Contribution of the Environmental Factors in Influencing the Plant-microbe Interaction

Disease triangle involving plant-pathogen-environment and the importance of environmental stresses (drought, heat, humidity and soil factors) in influencing the resistance or susceptibility, Role of environmental factors in influencing establishment and sustenance of introduced beneficial microbes.

Unit 2: Physiological and Molecular Basis for Predisposition or Endurance of Plant during Abiotic-biotic Stress Interaction

Plant-water relations and changes in physiology in deciding the microbe interaction with plants, Metabolites in deciding the microbe interaction with plants, Hormonal cross talk, signal transduction, role of R-genes and other defense pathways during the simultaneous exposure to abiotic stress.

VII. Practicals

- *In-planta* bacterial/fungal multiplication in plant under drought stress
- Detection of plant pathogens using molecular tools
- Stomatal conductance in plants under drought stress and pathogen stress
- Apoplast isolation from plants subjected to bacterial infection
- Virus induced gene silencing in plants
- Acetylene reduction assays to check nitrogen fixation in plant (The effect of beneficial microbes in plant)
- Biochemical analyses of beneficial and pathogen-effector proteins
- Plant colonization and disease or growth promotion scoring
- In-vivo detection of plant immune responses and their inhibition by effectors
- Estimation of phytoalexins, PR proteins, ACC deaminase and growth hormones in pathogen challenged plants
- Effect of plant microbe interaction on plant physiological processes, viz. photosynthesis, chlroroplast, transpiration, etc.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

1. understand how beneficial microbes enhance the plant immune system
2. comprehend how beneficial microbes stimulate plant growth
3. describe plant-microbe interaction
4. understand plant defense and susceptibility

X. Suggested Reading

- Jones JDG and Dangl JL. 2006 *The plant immune system. Nature* Vol. 444, Pages 323–329
- Dodds PN and Rathjen JP. 2010. *Plant immunity: towards an integrated view of plant–pathogen interactions. Nature Reviews. Genetics.* Vol. 11, Pages 539–548
- Baker B, Zambryski P, Staskawicz B, Kumar SPD. 1997. Science. *Signaling in Plant-Microbe Interaction*. Vol. 276
- *The role of abscisic acid in plant–pathogen interactions.* Mani BM and Felix Mauch. *Current Opinion in Plant Biology*. 2005 8: 409-414 2005.
- Loake G and Grant M. 2007. *Salicylic acid in plant defence—the players and protagonists. Current Opinion in Plant Biology*.10: 466-472
- Kent AD and Triplett EW. 2002. *Microbial Communities and Their Interactions in Soil and Rhizosphere Ecosystems. Annual Review of Microbiology*. 56: 211-236
- Whipps JM. 2001. *Microbial interactions and biocontrol in the rhizosphere. Journal of Experimental Botany*. 52: 487–511.
- Vandenkoornhuyse P, Quaiser A, Duhamel M, Van AL, Dufresne A. 2015. *The importance of the microbiome of the plant holobiont. New Phytologist*. 206: 1196-1206 .

- Suzuki N, Rivero RM, Shulaev V, Blumwald E and Mittler R. 2014. *Abiotic and biotic stress combinations. New Phytologist*. 203: 32-4.
- Atkinson NJ and Urwin PE. 2012. *The interaction of plant biotic and abiotic stresses: from genes to the field. Journal of Experimental Botany*, 63: 3523–3543.

General Source Information

- Matveeva T, Provorov N, Valkonen JPT. *Cooperative Adaptations and Evolution in Plant-Microbe Systems*. Frontiers Media SA.
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- Choudhary, Devendra K, Varma, Ajit, Tuteja, Narendra (Eds.). 2016. *Plant-Microbe Interaction: An Approach to Sustainable Agriculture* Eds: ISBN 978-981-10-2854-0; Springer
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- Tejesvi MV, Pirttilä AM, Frank AC. *Emerging Tools for Emerging Symbioses—Using Genomics Applications to Studying Endophytes* by Frontiers Media SA
- Jyoti Shah, Linda Walling. *Advances in Plant-Hemipteran Interactions*, by Frontiers Media SA.
- Huang JS. 2009. *Plant Pathogenesis and Resistance* (*Biochemistry and Physiology of Plant-Microbe Interactions),* Kluwer Academic Publishers.
- Day PR. 1973. *Genetics of Host Parasite Interaction*,W.HFreeeman and Company.
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- Bringel F and Couée I. 2015. *Pivotal roles of phyllosphere microorganisms at the interface between plant functioning and atmospheric trace gas dynamics. Front. Microbiol*. 6: 486. doi: 10.3389/fmicb.2015.00486.
- Lugtenberg B. (Ed.). 2015. *Principles of plant-microbe interactions***.** doi: https://doi.org/10.1007/978-3-319-08575-3.
- Velmourougane K, Saxena G, Prasanna R. 2017. *Plant-microbe interactions in the rhizosphere: mechanisms and their ecological benefits*. Singh D., Singh H., Prabha R. (eds) *Plant-Microbe Interactions in Agro-Ecological Perspectives*. Springer, Singapore. doi: https://doi.org/10.1007/978-981-10-6593-4_7.
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I. Course Title : Weed Biology and Physiology of Herbicide Action

II. Course Code : PP 610

III. Credit Hours : 2+0

IV. Why this course?

Weeds pose a serious threat to Crop production leading to a yield loss ranging from

30% to sometimes total failure. Weed management is a significant input on part of the producers. Chemical weed management through herbicides have been the most effective among various methods. Various herbicides with different modes of actions are used to control weeds. Prolonged chemical control has led to adverse environmental consequences and development of herbicide resistance. There is a need to understand the biology of weeds as well as herbicide actions at physiological and molecular levels for resistance management as well as development of more effective and less harmful chemicals for weed management. The aim of this course will be to apprise the students about these aspects of chemical weed control.

V. Aim of this course

The course is designed to provide both basic and applied knowledge on the weeds. It will help to understand the fundamental physiology, biochemistry, and molecular biology of herbicides and their effects on plants; To study the physiological and molecular mechanisms of herbicide resistance.

This course will provide knowledge on biology of weeds, classification and mode of action of herbicides, herbicide resistance and its management and environment friendly weed management strategies.

The course is organized as follows:

No.	Blocks	Units
1.	Weed Biology	1. Weed Biology and its Importance in Weed Management 2. Life Cycle and Population Dynamics of Weeds 3. Crop Weed Competition
2.	Physiology of Herbicide Action	1. Introduction to Herbicides 2. Mechanism of Action of Herbicides 3. Herbicide Resistance and its Management

VI. Theory

Block 1: Weed Biology

Unit 1: Weed Biology and its Importance in Weed Management

Introduction to weeds, Classification of weeds, Yield losses caused by weeds, Environmental impacts of invasive weed species, Aspects of Weed biology, Germination, Dormancy and growth behaviour of weed species, Effect of environmental factors on weeds, Adaptation of weeds to different ecologies

Unit 2: Life Cycle and Population Dynamics of Weeds

Growth duration and reproductive potential of weed species, Population dynamics, Weed Shift due to weed management, weed Seed Bank,

Unit 3: Crop Weed Competition

Understanding the nature of crop-weed competition, critical stages of crop weed competition, growth stages of weeds for improved control by herbicides

Block 2: Physiology of Herbicide Action

Unit 1: Introduction to Herbicides

Introduction, Chemistry and classification of herbicides by mechanism of action, HRAC Classification, Site of Actions, Application techniques, doses, active ingredients, formulations, Absorption and translocation of soil and foliar applied herbicides, Methods to increase the efficiency of soil and foliar applied herbicide – role of membranes, adjuvants, surfactants, synergists,

Unit 2: Mechanism of Action of Herbicides

Physiological and biochemical effects of herbicides: Effects on membrane structure and functions, cell division and cell development, Effects on chloroplast, photosynthesis, respiration, protein synthesis, synthesis of lipids, Molecular mechanism of action, Molecular mechanisms of herbicide resistance in relation to chloroplast gene expression,

Unit 3. Herbicide Resistance and its Management

Herbicide resistance-Definition, history, magnitude; Mechanisms of resistance: Target site and non-target site, cross and multiple resistances, Role of management practices on resitance development, Resistance management: Strategies; HR crops, Super weeds,

VII. Teaching methods/activities

- Lectures
- Assignment (Reading/Writing)
- Text Books / reference books and materials
- Student presentations

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the importance of weed biology in weed management
- Understand the mechanism of herbicide action
- Understand the problem of herbicide resistance development
- Appreciate and suggest sustainable weed management strategies

IX. Suggested Reading

- Inderjit (Ed). 2004. *Weed Biology and Management*. Springer Netherlands
- Monaco, TJ, Weller SC, Ashton FM. 2002. *Weed Science: Principles and Practices*. John Wiley and Sons Inc., New York
- De Prado R, Jorrin J, and Garcia-Torres L. 1997. *Weed and Crop Resistance to Herbicides*. Kluwer academic Publishers, The Netherlands.
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Restructured and Revised
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Biotechnology and Bioinformatics

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Executive Summary
(Bioinformatics)

- Bioinformatics has emerged as an interdisciplinary and integrated scientific discipline, which links the computational and statistical sciences with life sciences. A big hurdle in the development of Bioinformatics in India is the limited availability of trained human resource, faculty and Ph.D. scholars in the field. However, with the constant efforts put forth by ICAR and SAUs in recruiting ARS scientists/ Assistant Professors in bioinformatics, the problem of faculty shortage has been reduced to some extent. Also, the students from this discipline get motivated with such employment opportunities. Wherever the new recruitments take time, the faculty drawn from computer science, statistics, biotechnology, biochemistry disciplines may be sent for training in bioinformatics within India or at abroad. In order to reach the unreached discoveries and innovations through bioinformatics, one should have a reasonably good infrastructure with high-end servers, high-speed internet connectivity, CPU/GPU based high performance computing system, high storage, smart classrooms, open source software, Linux-Apache-MySQL-Perl/PHP (LAMP) technology, etc. The need of the hour is to deploy advanced techniques of artificial intelligence, machine learning and big data analytics to unravel the underlying mechanisms and factors involved in complex biological phenomena and thus, the syllabus has been revised in this light. Recent developments in bioinformatics have become indispensable for use in omics and systems biology approaches. Thus, these developments have now been made part of the syllabus as follows.
- Five new courses have been added including (i) “Non-Coding RNAs”, (ii) “Comparative and Functional genomics”, (iii) “Systems Biology”, (iv) “R and high dimensional genome data” and (v) “Big data analytics” to prepare the students for meeting the challenges arising out of complex genomes.
- Emphasis has been laid on disassociating the overlaps in the existing courses, incorporating the new concepts in the courses like network modelling and systems biology, machine learning techniques in bioinformatics, parallel programming and algorithm development so that any student after completing his M.Sc. degree in bioinformatics can discharge his duties both as bioinformaticist and bioinformatician.
- More emphasis was given on practicals so that the students can efficiently deal with the high dimensional data sets of Next Generation Sequencing (NGS), Genotype-By-Sequencing and Genome Wide Association Studies (GWAS) with special skills.
- The revised syllabus addresses the recent advances and modern concepts of AI, Machine Learning in analyzing big data coming from genomics, transcriptomics, proteomics and other omics researches.
- The demand for trained manpower in bioinformatics is increasing in private sector, which is a healthy sign for the PG students. Care has been taken while devising the syllabus to incorporate more practicals on computer programming and high-dimensional genome data analysis software.

Preamble

Driven by the recent developments in high throughput Genomics, Bioinformatics is taking an ever-increasing role in Agri-genomics. In a similar way, advances in information technology and computational methods are driving the mathematical sciences forward. Artificial Intelligence and Big Data analytics have revolutionized the bioinformatics-based genome data analysis. Now with the availability of next generation sequencing technologies, a high volume of both structured and unstructured data is available. Further, data is also available from many genome data repositories like GenBank at National Centre for Biotechnology Information in the public domain. All these have led to the availability of the huge amount of data from different agricultural organisms that need to be analyzed and elicit the hidden information for knowledge discovery to unravel the underlying complex biological phenomena.

In order to achieve the goals of bioinformatics: (i) designing of algorithms for handling and analysis of genomic big data (ii) development of statistical-computational methods and techniques, automated pipelines, tools for high dimensional genome data analysis (iii) accessing the existing databases and sharing the developed tools and databases in public domain; planning strategies and human resources are to be developed in genomics research to solve the national level problems and issues. To mention a few, the priority areas are: (i) plant and animal improvement through genomics-assisted breeding and genomic selection (ii) climate smart crop production for food security (iii) metagenome wide association study of soil microbiome with crop productivity by machine learning (iv) GWAS, PheWAS and phenomics aided improvement programmes (v) artificial intelligence (AI); machine learning – an approach to achieve AI; and deep learning– a technique for implementing machine learning; for knowledge discovery through agri-genomics (vi) blockchain technology and data science for agricultural value chain (vii) role of microbiota in plant and animal health care and expression of economically important traits (viii) designing and development of Agri-Encyclopedia of DNA Elements (A-ENCODE) (ix) identification of bioremediation bacteria and probiotics from Indian river system for pollution remediation (x) improved and efficient algorithms for robust genome assembly from data generated under different Next Generation Sequencing platforms. Possessing expertise and skills in computer programming languages like R and python is essential for bioinformaticians, who are developers of bioinformatics tools and pipelines in the system. Above all, there exists always a rapidly increasing demand for individuals to be trained in bioinformatics with special skills and knowledge to handle high dimensional genomic data. The emerging trends in genomic research, need for human resources for teaching and application of bioinformatics in genomic research for crop improvement, shrinking job opportunities in the public sector etc would warrant students to possess the technical knowledge and skills in bioinformatics coupled with good practical and management skills, to be competitive for both public and private sectors. Hence a thorough restructuring of course curriculum and delivery system is needed.

In this revised course curriculum of Bioinformatics, the BSMA sub-group organized a series of meetings to develop the courses for M.Sc. and Ph.D. programs for the NAREE system. The meetings were focused on keeping different courses on AI/ML/DL, programming languages, big data analytics in the curriculum without compromising on the quality and the content in terms of imparting the requisite up to date knowledge to the students. Thus, the basic platform courses are kept as core courses that need to be taken by all the students irrespective of the subject specialization from which they entered the PG education. The course curriculum also targets the M.Sc. and Ph.D. students separately by providing two sets of courses and advanced courses to the Ph.D. students only. Also, substantial inputs were provided by the experts to introduce recent developments in the advanced courses so that the concepts are ingrained when the M.Sc. graduates enter to the Ph.D. system. An additional input received during discussion was on enabling the SAUs and Deemed-to-be Universities to have reasonably good infrastructure that helps students to have comprehensive knowledge with hands on training. This will help the students build confidence in becoming entrepreneurs in bioinformatics, get employment in R&D companies so that the gains in education gets translated to the end user, the producers, processors and the consumers.

The opinions and suggestions invited from the institutions, eminent scientists and other stakeholders were revived by the BSMA sub-committee. The new look and restructured PG programme in bioinformatics has been designed by considering the needs of private sector, modern statistical and computational methods, algorithms, artificial intelligence and machine learning, and big data science to enhance the global competitiveness and employability of the students. Thus, considerable and markable efforts have gone into the preparation of the present revised course curriculum of Bioinformatics.

Course Title with Credit Load
M.Sc. in Bioinformatics

Course Code	Course Title	Credits (L+P)
	Major: 20 credits	
	(12 credits of core plus 8 credits of optional)	
BI 501	Introduction to Bioinformatics & Computational Biology*	2+1
BI 502	Statistical Genomics*	2+1
BI 503	Genome Assembly and Annotation	1+1
BI 504	Biomolecular Modelling and Simulation*	2+1
BI 505	Transcriptomics and Metagenomics	2+1
BI 506	Biological Data Management*	2+1
BI 507	Biological network modelling and analysis	2+1
BI 508	Computer programming in bioinformatics	2+1
BI 509	Machine Learning Techniques in bioinformatics	2+1
	Minor (8 credits)	
	Molecular Biology and Biotechnology	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Any other related discipline	
	Supporting (6 credits)	
	Statistics	
	Mathematics	
	Computer Science	
	Any other appropriate discipline	
	Common courses	5
BI	Seminar	0+1
BI 500	Research	0+30
	Total	70

*Core courses

Courses Contents
M.Sc. in Bioinformatics

I. Course Title : Introduction to Bioinformatics and Computational Biology

II. Course Code : BI 501

III. Credit Hours : 2+1

IV. Aim of the course

To provide theoretical and practical knowledge about handling and processing of genomic data, optimization and data mining techniques used in bioinformatics.

V. Theory

Unit I (15 Lectures)

Overview of available genomic resources on the web; NCBI/ EBI/ EXPASY etc; Nucleic acid sequence databases; GenBank/EMBL/ DDBJ; Database search engines: Entrez, SRS. Overview/concepts in sequence analysis; Pairwise sequence alignment algorithms: Needleman and Wunsch, Smith and Waterman; BLAST, FASTA; Scoring matrices for Nucleic acids and proteins: PAM, BLOSUM, Multiple sequence alignment: PRAS, CLUSTALW. Sequence based gene prediction and its function identification.

Unit II (5 Lectures)

Preprocessing of gene expression data; Data Normalization techniques, Data quality control: Modelling of errors, Imputation etc; High-throughput screening.

Unit III (6 Lectures)

Optimization Techniques: concept and applications, Simulated Annealing, Genetic Algorithms: *Ab initio* methods for structure prediction; Information theory, entropy and relative entropy.

Unit IV (6 Lectures)

Foundations for Machine learning Techniques: Unsupervised and Supervised Learning, Cross Validation Techniques, Markov Model, Bayesian Inference: concepts and applications, Hidden Markov Model and applications, Introduction to WEKA package.

VI. Practicals

Database Similarity Searches, Multiple sequence alignment, Genome databases, Structural databases, Derived databases, Gene annotation, Gene prediction software. Analysis of DNA microarray experiments, Expression profiling by microarray/gene chip, Proteomics, Pattern recognition, Hidden Markov Models, Gibbs Sampling, Analysis of single and multiple DNA or protein sequences.

VII. Suggested Reading

- Baldi, P. and Brunak, S. 2001. *Bioinformatics: The Machine Learning Approach*. MIT Press.
- Baxevanis, A.D. and Francis, B.F. 2004. *Bioinformatics: A Practical Guide to the Analysis of*

Genes and Proteins. John Wiley.
- Wang JTL, Zaki MJ, Toivonen HTT and Shasha D. 2004. Data Mining in Bioinformatics.Springer.
- Amaratunga D and Cabrera J. 2004. *Exploration and Analysis of DNA Microarray and Protein Array*. John Wiley.
- Gupta GK. 2006. *Introduction to Data Mining with Case Studies*. Prentice Hall of India, New Delhi.
- Han J and Kamber M. 2006. *Data Mining: Concepts and Techniques*. Morgan Kaufman.
- Hand DH, Mannila P Smyth. 2001. *Principles of Data Mining*. Prentice Hall of India, New Delhi.

I. Course Title : Statistical Genomics

II. Course Code : BI 502

III. Credit Hours : 2+1

IV. Aim of the course

This course builds the basic understanding of statistical methods used in genetics and genomics.

VI. Theory

Unit I (14 Lectures)

Fundamentals of Population genetics: Hardy –Weinberg law, Effect of systematic forces on changes in gene frequency; Principles of Quantitative genetics: Values, Means and Variances, Detection and Estimation of Linkage, Inbreeding, Selection, Genetic Parameter Estimation, Variance component estimation, BLUP, G x E interaction, Path Analysis

Unit II (10 Lectures)

Molecular Marker based classification: similarity measures, clustering methods, bootstrapping; QTL mapping: Detection and Estimation of QTL, Single Marker Analysis, Interval Mapping and MQM;

Unit III (8 Lectures)

Design and Analysis of Expression Data; Genome Selection; Genome Prediction, Genetic Markers, Association Mapping; Genome Wide Association Analysis

VII. Practicals (16 Lectures)

Population genetics: Hardy-Weinberg law, Estimation of linkage, Inbreeding, Selection, Genetic parameter estimation, Variance component estimation, BLUP, Path analysis, Molecular marker based classification, Estimation of QTL, Single marker analysis, MQM, Analysis of gene expression data, Genome selection and Genome prediction.

VIII. Suggested Reading

- Xu, Shizhong. 2013. *Principles of Statistical Genomics*. Springer
- Ben Hui Liu. 1997. *Statistical Genomics: Linkage, Mapping, and QTL Analysis.*
- Sorensen D and Gianola D. 2002. *Likelihood, Bayesian and MCMC Methods in Genetics.* Springer.
- Ben HL and Leming MS. 2013. *Statistical Genomics and Bioinformatics.*

I. Course Title : Genome Assembly and Annotation

II. Course Code : BI 503

III. Credit Hours : 2+1

IV. Aim of the course

The primary objective of this course is to develop practical understanding of techniques and tools used in genome assembly with emphasis on issues and challenges of its structural and functional annotation.

V. Theory

Unit I (6 Lectures)

Types and methods of genome sequence data generation; Shot gun sequencing method; Problems of genome assembly, Approaches of genome assembly: Comparative Assembly, DE novo Assembly; Read coverages; Sequencing errors, Sequence Quality Matrix, Assembly Evaluation; Challenges in Genome Assembly.

Unit II (5 Lectures)

Various tools and related methods of genome assembly: MIRA, Velvet, ABySS, ALLPATHS-LG, Bambus2, Celera Assembler, SGA, SOAP*denovo,* etc.

Unit III (5 Lectures)

Basic concepts of genome annotation; Structural and Functional Annotation; Identification of open reading frame (ORF) and their regularization, Identification of gene structure, coding regions and location of regulatory motifs

VI. Practicals (16 Lectures)

Genome assembly methods for data from various sequencing platform, Sequencing error determination, Sequence quality matrix; Various tools for genome assembly: MIRA, Velvet, ABySS, ALLPATHS-LG, Bambus2, Celera Assembler, SGA, SOAP *denovo*, etc. Structural and functional Genome annotation.

VII. Suggested Reading

- Jung, S., Paul, Gordon, M.K., Sensen, C. W. 2012. *Genome Annotation*. Chapman and Hall/ CRC
- Venter, J. C., 2000. *Annotation of the Celera Human Genome Assembly*. Celera.
- Mark Menor. 2007. *Multi-genome Annotation of Genome Fragments Using Hidden Markov Model Profiles*
- Carson Hinton Holt. 2012. *Tools and Techniques for Genome Annotation and Analysis*
- Alistair G. Rust, Emmanuel Mongin and Ewan Birney Loraine A.E and Helt G.A. 2002. *Genome annotation techniques: new approaches and challenges. Drug Discovery Today*. 570-576 p.
- Weizhong Li and Adam Godzik. 2002. *Discovering new genes with advanced homology detection. Trends in Biotechnology*, 20: 8, 315-316 p.

I. Course Title : Bio-molecular Modelling and Simulation

II. Course Code : BI 504

III. Credit Hours : 2+1

IV. Aim of the course

The course aimed to develop understanding of bio molecular modelling techniques and simulation.

V. Theory

Unit I (8 Lectures)

Methods for 3D Structure Prediction: Homology modeling of protein 3D structures – approaches to loop building, energy considerations and evaluation of the accuracy of the model. *ab initio* approach to 3D structure prediction; Threading approach to 3D structure prediction. A Comparison of protein structure prediction methods: CASP

Unit II (8 Lectures)

Basic principles of modeling, modeling by energy minimization technique, concept of rotation about bonds, energy minimization by basic technique for small molecules, Ramachandran plot, torsional space minimization, energy minimization in Cartesian space, molecular mechanics-basic principle

Unit III (8 Lectures)

Basic concepts of Simulation Modelling: Units and derivatives, Force field and energy landscape, Truncation of non-bonded interactions, Introduction to solvation, Periodic boundary condition, Wald summation, implicit solvent model and continuum electrostatics, Monte Carlo simulation on parallel computers. Replica-exchange simulations, Restraint potentials, Free energy calculations, Membrane simulations

Unit IV (8 Lectures)

Energy Minimization: Concept of energy minimization - hypersurface, local and global energy minima, statement of problem. Derivative minimization methods - first derivative methods: the steepest descents method, line search in one dimension, arbitrary step approach, conjugate gradients minimization. Second derivative method – the Newton-Raphson method. Applications of energy minimization.

VI. Practicals: (16 Lectures)

Protein structure databases: PDB, MODBASE, Structure visualization – Rasmol and PyMol, Structural analysis- classification, CATH, SCOP, Protein geometry – bond length, bond angle, torsion angle, calculation of surface area, volume and radii: Swiss PDB Viewer. Small molecule generation - peptides and nucleic acids: ISIS draw / ChemSketch, Selection of query sequence, template selection: pdbBLAST, Comparative 3D structure prediction – SWISSMODEL, Model generation - building side chains and loops using Modeller, Threading, *ab initio* modeling, Structure validation - generation and analysis of Ramachandran plot using PROCHECK, WHATCHECK via SAVS server, Force field calculation and energy minimization, Structure refinement - loop building, removing non-bonded contacts, adding missing side chains via WhatIf interface, Scoring structural similarity - 3D structure alignment - RMS superimposition – VMD, Molecular dynamics simulation using Tinker. Simulation dynamics, Monte carlo simulation on parallel computers. Replica exchange simulation, free energy calculation. Docking

VII. Suggested Reading

- Schlick T. 2010. *Molecular Modeling and Simulation: An Interdisciplinary Guide*. Science.
- Gunsteren WF, Weiner PK, Wilkinson AJ. 1997. *Computer Simulation of Biomolecular Systems: Theoretical and experimental application*. Springer.
- Martin JF. 2007. *A Practical Introduction to the Simulation of Molecular Systems*. Cambridge University Press.
- Leach AR. 2001. *Molecular Modeling: Principles and Applications*. Prentice Hall. 784p.

- Bourne PE and H Weissig. 2003. *Structural Bioinformatics*. Wiley-Liss. 650 p.
- Marx D and Hutter J. 2009. *Ab Initio Molecular Dynamics: Basic Theory and Advanced Methods*. Cambridge University Press. 578p.

I. Course Title : Transcriptomics and Metagenomics

II. Course Code : BI 505

III. Credit Hours : 2+1

IV. Aim of the course

The course aims to teach basic concepts of metagenomics and various techniques used in the analysis of metagenomic data

V. Theory

Unit I (8 Lectures)

Microarrays, RNA-seq, Chip-Seq, EST-clustering, differential expression analysis

Unit II (6 Lectures)

Taxonomic and genetic annotation of high throughput sequence data, microbial diversity analyses, analyses of microbial community composition and change and metabolic reconstruction analyses.

Unit III (9 Lectures)

Comparison between Metagenomics and AL, EC, Comparison between LCS and Metagenomics, Symbiotic Evaluations: SANE, Comparison between SANE and Metagenomics, Horizontal Gene Transfer: Microbial GA.

Unit IV (9 Lectures)

Metagenome Sequencing, Single Cell Analysis, Host-Pathogen Interaction; Shotgun metagenomics; High-throughput sequencing; Comparative metagenomics; Community metabolism; Metatranscriptomics.

VI. Practicals (16 Lectures)

Meta genome annotation, Analyses of microbial community composition and change and metabolic reconstruction analyses; Metatranscriptomics; Comparative metagenomics. Microarray data analysis; RNA-seq, chip-seq, EST-clustering.

VII. Suggested Reading

- Diana marco. 2010. *Metagenomics: Theory, Methods and Applications*. Ceister academic press
- Streit WR and Daniel R. 2010. *Metagenomics: Methods and Protocols*. Springer protocols.
- Yeh WK, Yang H, McCarthy JR. 2010. *Enzyme Technologies: Metagenomics, Evolution, Biocatalysis and Biosynthesis*.wiley
- Muthukumar V. 2003. *Metagenomics for the Identification of Plant Viruses*. ProQuest.

I. Course Title : Biological Data Management

II. Course Code : BI 506

III. Credit Hours : 2+1

IV. Aim of the course

The course aims at teaching database management system and familiarizing with the techniques of data sources, data curation and integration of data sources

V. Theory

Unit I (6 Lectures)

Database Management System (DBMS): Need for DBMS - File system vs Database system, Advantages of DBMS - DBMS Architecture – DBMS services - Data abstraction - Overview of Data Models: Hierarchical Model - Network Model - Entity-Relationship (E-R) Model: Symbols - Components of E-R Model: Entities, Attributes, Relationships - Relational Model, Object-oriented Model.

Unit II (8 Lectures)

Overview of Relational Database Objects – Relation – Tuple - Cardinality – Attribute – Degree - Domain - Primary key – Foreign key - Relational data structure – Relational Data Integrity and Constraints: Domain constraints, Entity integrity, Referential Integrity, Operational constraints - Codd's Rules – Normalization: 1NF, 2NF, 3NF, BCNF, 4NF and 5NF.

Unit III (8 Lectures)

Structured Query Language (SQL): Overview of SQL – SQL Data types and Literals – SQL Commands: Data Definition Language (DDL), Data Manipulation Language (DML), Data Querying Language (DQL), Data Control Language (DCL), Data Administration Statements (DAS), Transaction Control Statements (TCS), SQL Operators: Arithmetic, Comparison, Logical and Set Operators – SQL Query, Nested Query - SQL Aggregate functions.

Unit V (10 Lectures)

Curation of genomic, genetic, proteomic data, High-throughput screening, array, qPCR data sets; Quality management of data: tools and techniques. Biological data sources, Data granularity, Schema modelling, architecture, query design, extraction, transformation and loading, Long term data management, storage and security. Bio-chip information system, visualization and reporting, Risk factors for data quality management. Un-structured or noSQL database; AI and BIG data Analytics

VI. Practicals (16 Lectures)

Understanding the data sources, Data granularity, Data modeling and architecture, development of database, Storage, Security, Visualization and reporting.

VII. Suggested Reading

- Kozak K. 2010. *Large scale data handling in biology*. Ventus Publishing ApS. ISBN 978-87-7681-555-4.
- Harold, E. and Means W.S. 2004. *XML in a Nutshell*, Third Ed. O'Reilly, Sebastopol, CA
- Witten, I.H. and Frank E. 2005. *Data Mining: Practical Machine Learning Tools and Techniques* (WEKA), 2nd Ed. San Francisco, Morgan Kaufmann,
- Lodish, H. *et al*. 2000. *Molecular cell biology*. New York: Freeman & Co.
- Kaneko K. 2006. *Life: An Introduction to Complex Systems Biology*. Springer.

I. Course Title : Biological Network Modelling and Analysis

II. Course Code : BI 507

III. Credit Hours : 2+1

IV. Aim of the course

This course aims to develop basic understanding of system biology through biological network modelling and its analysis.

V. Theory

Unit I (12 Lectures)

Introduction to biological networks, Graph theoretic modelling and analysis of biological networks, Discrete Dynamic modelling (Boolean networks, Petri nets), Continuous dynamic modelling (ODEs, stochastic simulation, etc.)

Unit II (12 Lectures)

Probabilistic modelling (Probabilistic Boolean networks, Bayesian networks, Mutual Information), Network inference from experimental data, Genome-scale modelling and network integration

Unit III (8 Lectures)

Evolution of molecular networks, Network-guided GWAS studies, FBA and epistasis detection, protein function prediction

VI. Practicals (16 Lectures)

Biological networks, Graph theoretic modelling and analysis of biological networks, Discrete Dynamic modeling; Continuous dynamic modeling; Probabilistic modeling; Genome-scale modelling and network integration; Evolution of molecular networks, Network-guided GWAS studies, FBA and epistasis detection, protein function prediction.

VII. Suggested Reading

- Junker BH. 2008. *Analysis of Biological Networks*.
- Koch I Reisig, W. Schreiber F. 2010. *Modeling in Systems Biology: The Petri Net Approach*.
- Ramadan EY. 2008. *Biological Networks: Modeling and Structural Analysis*.
- Laubenbacher R. 2007. *Modeling and Simulation of Biological Networks.*

I. Course Title : Computer Programming in Bioinformatics

II. Course Code : BI 508

III. Credit Hours : 2+1

IV. Aim of the course

To learn programming skills for parsing biological data, parallel computing, database connectivity and web-interface.

V. Theory

Unit I (7 Lectures)

BioJava- Packages, Data Import, Manipulation; Python- Basic Syntax, Loops, Functions; BioPython.

Unit II (7 Lectures)

Bioperl: Introduction, Modules: SeqIO, SearchIO, Seq Feature, Finding introns, Alignments, LiveSeq and Tree.

Unit III (12 Lectures)

OpenMP: Clauses, Worksharing constructs, Synchronization constructs, Environment variables, Global Data, Runtime functions, Message Passing Interface (MPI): Introduction and programming, Point to point communications, Collective communications, Advanced MPI1 concepts, MPI2 introduction, Hybrid (openMP + MPI) programming.

Unit IV (6 Lectures)

Compute Unified Device Architecture (CUDA): Introduction and Programming, GPU computing.

VI. Practicals (16 Lectures)

BioPerl programing using bioperl modules such as SeqIO, SearchIO, LiveSeq and Tree; OpenMP programming on Work sharing and Synchronization constructs, Environment variables and global data; MPI programming on Point to point communications and Collective communications; Compilation of OpenMP and MPI programs; Execution of OpenMP and MPI programs; Use of high performance computing, computing resources and job scheduling.

VII. Suggested Reading

- Tisdall J. 2001. *Beginning Perl for Bioinformatics*. O-Reilly.
- Schwartz RL, Phoenix T, Foy BD. 2008. Learning Perl. O-Reilly.
- Orfali R and Harkey H. 1999. *Client/Server Programming with JAVA and CORBA*. John Wiley.
- Sriram Srinivasan. 1997. *Advanced Perl Programming*. O-Reilly.
- Bunce T and Descartes A. 2000. *Programming the Perl DBI*. O-Reilly.
- Mitchell L Model. 2010. *Bioinformatics Programming Using Python*, O'Reilly media, Cambridge, Bal HP 2003. *Perl Programming for Bioinformatics*, Tata McGraw Hill.

I. Course Title : Machine Learning Techniques in Bioinformatics

II. Course Code : BI 509

III. Credit Hours : 2+1

IV. Aim of the course

The purpose of the course is to explain various machine learning techniques and its applications on biological data.

V. Theory

Unit I (10 Lectures)

Introduction to statistical learning theory, Empirical Risk Minimization, Structural Risk Minimization; Classification: Decision tree, Bayesian, Rule based classification, ANN, SVM, KNN; Case based reasoning and Applications in Bioinformatics.

Unit II (12 Lectures)

Clustering: Partition Methods, Heirarchical methods, Density based methods, Grid based clustering, Model based clustering, clustering of high dimensional data, constraints based clustering, Analysis of MD trajectories, Protein Array data Analysis.

Unit III (10 Lectures)

Dimensional Reduction Techniques, Methods of Feature Selection, Resampling Techniques, Elements of Text Mining and Web Mining, Soft Computing and Fuzzy logic system and application in bioinformatics.

VI. Practicals (16 Lectures)

Decision tree, classification techniques: ANN, SVM, KNN, Case based reasoning and its applications on biological data. Clustering techniques; Clustering of high dimensional data; Dimensional reduction techniques; Resampling techniques; Text mining and Web mining. Soft Computing and Fuzzy logic system & application in bioinformatics.

VII. Suggested Reading

- Witten, H.I., Frank, E. and Hall, M.A. 2011. *Data Mining: Practical Machine Learning Tools and Techniques*.
- Hastie, T., Tibshirani, R., Friedman, J.H. 2009. *The Elements of Statistical Learning: Data Mining Interface and Prediction*.
- Clarke, S.B., Fokoue, E. and Zhang, H.H. 2009. *Principles and Theory for Data Mining and Machine Learning*.

Course Title with Credit Load
Ph.D. in Bioinformatics

Course Code	Course Title	Credits (L+P)
	Major: 12 credits	
	(5 credits of core plus 7 credits of optional)	
BI 601	Genome wide association study*	2+1
BI 602	#Computational analysis of Non-coding RNAs	1+1
BI 603	#Big data analytics	1+1
BI 604	#Systems Biology	3+0
BI 605	#Comparative and functional genomics*	1+1
BI 606	Phylogenetics	2+1
BI 607	#R and high dimensional genome data	1+1
BI 608	Pharmacogenomics & IPR	3+1
BI 609	Biological data integration and quality control	1+1
BI 610	Quantum theory and applications in bioinformatics	1+1
	Any other from 500 series	
	Minor (6 credits) – Any one/two of the following disciplines	
	Molecular Biology and Biotechnology	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Supporting (5 credits) Any from the following disciplines	
	Statistics	
	Mathematics	
	Computer Science	
	Common Courses	
BI	Seminar I	0+1
BI	Seminar II	0+1
BI 600	Research	0+75
	Total	**100**

Course Contents
Ph.D. in Bioinformatics

I. Course Title : Genome Wide Association Study

II. Course Code : BI 601

III. Credit Hours : 2+1

IV. Aim of the course

To introduce the concepts, principles, various designs and techniques of genome wide association study.

V. Theory

Unit I (12 Lectures)

Definition, Allelic spectra of common diseases, Allele frequencies for susceptibility loci, Risks associated with disease-susceptibility variants, Applications of linkage-disequilibrium metrics, SNP map, Genome resequencing for full coverage in genome-wide association studies, Transmission Disequilibrium Test, common variant hypothesis, rare allele hypothesis, Genome-wide graph theory algorithms

Unit II (12 Lectures)

Case-Control design, Trio design, Cohort design, Cross-sectional designs for GWAS Selection of Study Participants, Environmental confounders in GWAS, Confounding by population stratification, Genotyping and Quality Control in GWA Studies, Analysis of association between SNP and traits.

Unit III (8 Lectures)

Uses of GWAS: gene-gene interaction, detection of candidate haplotypes, association between SNPs and gene expression.

VI. Practicals (16 Lectures)

Allelic spectra of common diseases, Allele frequencies for susceptibility loci, linkage-disequilibrium metrics, SNP map, Genome resequencing for full coverage in GWAS; Case-Control design, Trio design, Cohort design, Cross-sectional designs for GWAS Selection; Genotyping and Quality Control in GWA Studies; Analysis of association between SNP and traits.

VII. Suggested Reading

- Qin H. 2008. *Statistical Approaches for Genome-wide Association Study and Microarray Analysis*.
- Yang C. 2011. *SNP Data Analysis in Genome-wide Association Studies*.
- Kraft JS. 2010. *Genome-wide Association Study of Persistent Developmental Stuttering.*

I. Course Title : Computational analysis of Non-coding RNAs

II. Course Code : BI 602

III. Credit Hours : 1+1

IV. Aim of the course

To introduce non-coding RNAs, its role and regulation in model organisms and tools and methods for *in silico* analyses

V. Theory

Unit I (8 Lectures)

Course overview; RNA molecules: biogenesis, types, structure and functions. Introduction to ncRNAs: types of ncRNAs, small ncRNAs, long ncRNAs, function of ncRNAs, Role of ncRNAs in plants and animals

Unit II (6 Lectures)

Small ncRNA**:** Introduction, miRNAs, siRNAs, hiRNAs, piRNAs, shRNAs; Post-transcriptional processing of microRNA; microRNA: target pairing and RISC function; miRNA target genomics; Functions and roles of miRNAs in growth & development of plants and animals. Stress responsive miRNAs, oncomiRs & tumour suppresser miRNAs.

Unit III (6 Lectures)

lncRNAs: biogenesis, classifications, structure and function of lncRNAs. Endogenous target mimic lncRNAs, triplet associated lncRNAs (miRNA, mRNA, lncRNAs); Circular RNAs: structure and functions. Role of circular RNA in cancer, growth and development.

Unit IV (6 Lectures)

Splicing and splice variants; Alternative splicing; Alternative splicing regulation; Nonsense mediated RNA decay; RNA editing.

Unit-V (6 Lectures)

Coding and non-coding sequences; TEs; lincRNAs and lncRNAs; Bacterial RNAs; riboswitches; Introduction to CRISPRs.

VI. Practicals (16 Lectures)

Exploration of databases and tools for identification and characterization of ncRNAs (miRNA, lncRNAs, circular RNAs); Prediction and characterization of ncRNAs from RNA-seq profiles; Structure prediction and validation of ncRNAs; Generation of new ncRNA resources and submission to genomic databases.

VII. Suggested Reading

- Ernesto Picardi Eds. 2015. *RNA bioinformatics*. Springer
- Ruzyo, G. J., and Walter, L., (Eds.) 2014. *RNA sequence, structure and function: computational and bioinformatic methods* –Springer
- Krebs, J. E., Lewin, B., Goldstein, E. S., Kilpatrick, S. T., 2014. *Lewin's Genes XI*- Jones & Bartlett Publishers
- MRS Rao. (ed.). 2017. *Long non-coding RNA biology*, springer
- Darnell J. 2011. *RNA: Life's indispensable molecule* – CSH press
- Krishnarao A. 2008. *MicroRNA-from basic science to disease biology*-Cambridge univ press

I. Course Title : Big Data Analytics

II. Course Code : BI 603

III. Credit Hours : 1+1

IV. Aim of the course

To introduce concepts of Big Data, Handling of unstructured genomic data using Big data analytics based tools.

V. Theory

Unit I (5 Lectures)

Big Data- Concepts, characteristics and relevance; MapReduce – Algorithm and application. Programming Models for Big Data.

Unit II (3 Lectures)

Hadoop framework, Hadoop Distributed File System (HDFS), YARN.

Unit III (5 Lectures)

Big Data SQL: – Hive Data Definition Language, Hive Data Manipulation Language, Hive Analytics: RegexSerDe, Views.

Unit IV (3 Lectures)

Apache Spark: Spark SQL, Spark DataFrame; PIG

VI. Practicals (16 Lectures)

Hadoop environment setup, HDFS, Spark SQL, Hadoop MapReduce, YARN, Hive, PIG.

VII. Suggested Reading

- Zikopoulos, P. C., Eaton, C., DeRoos, D., Deutsch, T., and Lapis, G. 2012. *Understanding big data: Analytics for enterprise class hadoop and streaming data* (p. 176). New York: Mcgraw-hill.
- Gandomi, A., and Haider, M. 2015. *Beyond the hype: Big data concepts, methods, and analytics*. *International Journal of Information Management*, *35*(2), 137-144.
- Akerkar R. (Ed.). 2013. *Big data computing*. CRC Press.
- Prajapati, V. 2013. *Big data analytics with R and Hadoop*. Packt Publishing Ltd.

I. Course Title : Systems Biology

II. Course Code : BI 604

III. Credit Hours : 3+0

IV. Aim of the course

This course provides emphasis on synthetic biology, modeling of genetic networks, cell-cell interactions, and evolutionary dynamics.

V. Theory

Unit I (16 Lectures)

Basic concepts in networks and chemical reactions; Input function of a gene, Michaelis-Menten kinetics, and cooperativity; Autoregulation, feedback and bistability; Introduction to synthetic biology and stability analysis in the toggle switch; Oscillatory genetic networks, Graph properties of transcription networks, Feed-forward loop network motif.

Unit-II (8 Lectures)

Introduction to stochastic gene expression, Causes and consequences of stochastic gene expression, Stochastic modeling—The master equation, Fokker-Planck Equation, and the Gillespie algorithm

Unit III (12 Lectures)

Introduction to microbial evolution experiments, and optimal gene circuit design, Evolution in finite populations, genetic drift, and the theory of neutral molecular evolution; Clonal interference and the distribution of beneficial mutations, Fitness landscapes and sequence spaces.

Unit IV (12 Lectures)

Evolutionary games; Survival in fluctuating environments, Parasites, the evolution of virulence and sex; Interspecies interactions, the Lotka-Volterra model, and predator-prey oscillations; Ecosystem stability, critical transitions, and the maintenance of biodiversity; Dynamics of populations in space, The neutral theory of ecology.

VI. Suggested Reading

- Alon, Uri. 2006. *An Introduction to Systems Biology: Design Principles of Biological Circuits*. Chapman & Hall / CRC. ISBN: 9781584886426.
- Nowak, M. A. 2006. *Evolutionary Dynamics: Exploring the Equations of Life*. Belknap Press, ISBN: 9780674023383.
- Bruce A. 2009. *Essential Cell Biology*. Garland Science, ISBN: 9780815341291.
- Strogatz, Steven H. 2014. *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering*. Westview Press, ISBN: 9780813349107.
- L. AlberghinaH.V.westerhoff, 2005. *Systems Biology: Definitions and perspectives* Springer.
- A.Kriete, R.Eils,. 2014. *Computational systems biology* Second edition, Academic Press
- E.KlippR.Herwig, A.Kowlad, C.Wierling and H.Lehrach 2005. *Systems Biology in practice: Concepts, Implementation and applications*, WileyInterScience.
- Pengcheng Fu, Panke S. 2009. *Systems Biology and Synthetic Biology* Wiley InterScience.
- Rigoutsos I. and G. Stephanopoulos G. 2007. *Systems Biology* Vol.1: Genomics Oxford University Press Inc., USA.
- Choi S. 2007. *Introduction to Systems Biology*. Humana press Inc, New Jercy, USA.
- A.Kriete, R. Eils 2014. *Computational Systems Biology* (Second edition) Academic Press.

I. Course Title : Comparative and Functional Genomics

II. Course Code : BI 605

III. Credit Hours : 1+1

IV. Theory

Unit 1 (8 Lectures)

Functional elements, Chromosomes and transposons, Organellar Genomes, Symbiosis, Horizontal gene transfer, Gene duplication, Ploidy, Gene fates, Pan and core genomes, Recombination, Transposons, Gene clustering, SNPs and HapMaps, GWAS. Comparative methods for detection of species / organism relationships, Domain evolution, Study of co-evolution: Plant-insect interactions. Host-parasite interactions, viral evolution.

Unit II (8 Lectures)

Pre-and post-genomic era; major advancements in genomic approaches; epigenetics and metagenomics; forward versus reverse genetics, Genome editing approaches and their applications; gene expression analyses and applications. RNAi. DNA chips and their use in transcriptome analysis, qPCR, SAGE, MPSS. Connecting Traits to Genes, and Genes to Functions; protein-protein interaction, and protein networks.

V. Practicals (16 Lectures)

Getting started on the HPC, Regular expressions, Unix and basic sequence statistics Databases, Genome browsers, Blast & HMMER, Short sequence alignments, Distance trees, Maximum likelihood trees, Whole Genome Alignments, DotPlots, CoGeWebTool, AntiSMASHWebTool

VI. Suggested Reading

- Brown TA. 2006. *Genomes. 3rd edition. Garland Science*, New York.
- Sankoff D and Nadeau JH. 2000. *Comparative Genomics: Empirical and Analytical Approaches to Gene Order Dynamics, Map Alignment and the Evolution of Gene Families.* Netherlands, Kluwer Academic Publisher
- Jonathan Pevsner. 2009. *Bioinformatics and Functional Genomics*. Wiley Blackwell
- Wilkins MR, Williams KL, Appel RD, Hochstrasser DF. (Eds) 1997. *Proteome Research: New Frontiers in Functional Genomics*. Springer Verlag Berlin Heidelberg
- Gupta PK and Varshney RK. 2009. *Cereal genomics*.
- Grotewold E. 2006. *Plant Functional Genomics. Methods in Molecular Biology* Vol 236.
- Azuaje F and Dopazo J. 2005. *Data Analysis and Visualization in Genomics and Proteomics*. John Wiley & Sons, US
- Primrose S.B and Twyman R. 2003. *Principles of Genome Analysis and Genomics*. Third Edition.
- Baxevanis. A. D. and Ouellette. B. F. F. (Eds). 2001. *Bioinformatics: A Practical guide to the analysis of genes and proteins.* Wiley Interscience. New York. 470p.
- Hunt and Livesey. 2000. *Functional Genomics: A Practical Approach*. Oxford University Press.
- Jollès P and Jörnvall H. 2000. *Proteomics in Functional Genomics: Protein Structure Analysis*. Birkhäuser.
- Branden. C and J. Troze. 1999. *Introduction to Protein Structure*. Second Edition.
- Brown TA. 2002. *Genomes* IInd Edition. Oxford Wiley Press (ISBN-10: 0-471-25046-5)
- Yun Bi Xu. 2009. *Molecular Plant Breeding*. CABI (ISBN: 978 1 84593 392)

I. Course Title : Phylogenetics

II. Course Code : BI 606

III. Credit Hours : 2+1

IV. Aim of the course

To find out the evolutionary relationship among various species by using different phylogenetic techniques and algorithms.

V. Theory

Unit I (14 Lectures)

Phylogenetic trees and their comparison: Definition and description, various types of trees; Consensus (strict, semi-strict, Adams, majority rule, Nelson); Data partitioning and combination Tree to tree distances, similarity; Phylogenetic analysis algorithms: Maximum Parsimony, Distance based: UPGMA, Transformed Distance, Neighbors-Relation, Neighbor-Joining.

Unit II (18 Lectures)

Probabilistic models of evolution, Maximum likelihood algorithm; Approaches for tree reconstruction: Character optimization; delayed and accelerated transformation, Reliability of trees, Bootstrap, jackknife, decay, randomization tests; Applications of phylogeny analyses: Comparison of Phylogenetic Trees obtained using DNA seq. vs. protein seq. vs. Full genomes. Need for addition of other properties towards total phylogenetic analysis, Comparative methods for detection of species/ organism relationships, Gene duplication, Horizontal transfer, Domain evolution, Study of co-evolution: Plant-insect interactions. Host-parasite interactions, viral evolution.

VI. Practicals (16 Lectures)

Different software for phylogenetic tree construction and evolution of tree such as EMBOSS, MrBayes, PAUP, PHYLIP, PAML, TREE puzzle, Dandogram, cladogram analysis.

VII. Suggested Reading

- Hall, B. G. 2001. *Phylogenetic Tress Made Easy: A How to Manual for Molecular Biologists*. SinauerAss.,USA.
- Nei, M. and Kumar, S. 2000. *Molecular Evolution and Phylogenetics*. Oxford University Press.
- Sankoff, D. & Nadeau JH. 2000. *Comparative Genomics: Empirical and Analytical Approaches to Gene Order Dynamics, Map Alignment and the Evolution of Gene Families*. Netherlands, Kluwer Academic Publisher
- Gustavo Caetano. 2010. *Evolutionary Genomics and Systems Biology*. Wiley-blackwell.
- Mount.D.W.2001. *Bioinformatics: Sequence and Genome Analysis*. Cold Spring Harbor Laboratory Press. New York. 564 pp.
- Nei M and Kumar S. 2000. *Molecular Evolution and Phylogenetics* Oxford University Press.
- Engels J.M.M, RamanathaRao.V, Brown.A.H.D and Jackson.M.T, 2002. *Managing Plant Genetic Diversity*, CABI Publishers, CAB International UK 489pp.

I. Course Title : R and High Dimensional Genome Data

II. Course Code : BI 607

III. Credit Hours : 1+1

IV. Aim of the course

This course mainly aims at teaching R and its packages, programming to the students and make them acquainted with the use of R for data analysis, in general, and genomic data analysis, in particular.

V. Theory

Unit I (8 Lectures)

R programming language: Introduction and basics, R data types- Arithmetic and Logical Operators. R Matrix- Create, Print, add Column, Slice; R Data Frame- Create, Append, Select, Subset, Sort; List in R- Create, Select; R Functions; If, Else, Else If statements in R; For loop and While Loop in R; Data Importing and Exporting; Correlation, Anova, T test , Simple and Linear Regression, Scatter Plot, Bar Chart and Histogram in R; Memory management;

Unit II (8 Lectures)

Applications of R: Univariate and Multivariate phenotypic data analysis; Linear Models – fixed effects model, random effects model, mixed effects model for genetic parameter estimation; GGE Biplot and AMMI for Stability analysis; Gene Expression analysis – Microarray and RNA-Seq data; Genome Wide Association Study (GWAS), Genomic Selection (GS), Sequence analysis; Genome Assembly and Annotation; Machine Learning – ANN, SVM, Random Forest, Deep Learning.

VI. Practicals (16 Lectures)

Matrix Operations In R; R Data Frame, Functions in R, Correlation in R, Simple and Linear Regression in R. ANOVA in R, Other applications of R for crop and animal improvement.

VII. Suggested Reading

- Ihaka R and Gentleman R. 1996. *R: a language for data analysis and graphics*. *Journal of computational and graphical statistics*, *5*(3), 299-314.
- Gentleman R. 2008. *R programming for bioinformatics*. Chapman and Hall/CRC.

I. Course Title : Pharmacogenomics and IPR

II. Course Code : BI 608

III. Credit Hours : 3+1

IV. Theory

Unit I (8 Lectures)

Introduction to Drugs: Sources of drug- plant, animal, microbes, minerals. Drug name – chemical name, brand name or trade name, general name or common name. Drug classification – Chemotherapeutic agents, Pharmacodynamic agents, Miscellaneous agents. Routes of administration – Oral route and Parental route. Drug Absorption, Distribution, Metabolism and Excretion (ADME).

Unit II (8 Lectures)

Drug Response to Genetic Variations: SNP as markers in Pharmacogenomics-Turning SNPs into Useful Markers of Drug Response. Mechanism of drug action – receptor, agonist, ion channel. Inheritance and drug response - Pharmacogenetics of drug metabolism – Phase I metabolism, Phase II metabolism. Pharmacogenomics of Drug Transporters- Organic Anion and Cation Transporter Family, Peptide Transporter Family, Multidrug Resistance-Associated Proteins.

Unit III (6 Lectures)

Case Studies in Pharmacogenomics: Pharmacogenomics of Chemotherapeutic Agents in Cancer Treatment, Pharmacogenomics of Neurodegenerative Diseases: Examples and Perspectives, Pharmacogenomics of Alcoholism, Ethnicity and Pharmacogenomics. Ayugenomics. Pharmacogenomics and pharmaceutical Industries.

Unit IV (8 Lectures)

Basics of Toxicogenomics: Definition, genetic polymorphisms, Comparative toxicogenomics database (CTD) – Chemical gene interaction, chemical – disease association, gene – disease association. Specific applications of toxicogenomics – xenobiotics – insecticide - exposure assessment, hazard screening, variability of susceptibility, mechanistic information, cross-species extrapolation, dose-response relationship, development exposures, mixture.

Unit V (6 Lectures)

Databases for Toxicogenomics: Sample collection and data uniformity. Sharing and distributing data. Building toxicogenomic databases. ToxicogenomicDataRepositories – Standardization, availability, transparency. Data repositories - Stanford Microarray Database, CaBIG, DrugMatrix database, Tox-Express.

Unit VI (12 Lectures)

WTO and TRIPS Agreement: World Trade Organization (WTO)-Globalization-Trade Related Intellectual Property Rights (TRIPs) -General Obligations–substantive requirement of the TRIPS agreement in the WTO –International Union for the Protection of New Varieties of Plants (UPOV)- Multilateral treaties on patent

Forms of IPR and Role of Institutions: Different forms of IPR-Patents, Copyrights, GIs, Trademarks, Industrial Designs and Layouts, Trade secrets – Types of IPR forms-Utility, Design and plant patents, Generic and descriptive trademarks Role of Indian Patent Office (IPO), National Association of Creators, Owners and Users of Intellectual Property (NIPO), Geographical Indications (GI) registry-Multilateral organizations- World Intellectual Property Organization (WIPO), European Patent Office (EPO), US Patent and Trademark Office (USPTO),

Biotechnology and IP Rights: Biotech market in India- Biotech: SWOT – Bioinformatics in India – patent claims in biotechnology – patentable and non-patentable biotech inventions- patenting microorganisms and GMOs - Utility patents for genetic materials-patenting of biotech research tools - Types of bioinformatics patents -Infringement laws at National and International level- Acquisition / licensing of bio-tech patents and trade secrets.

IP Issues in Biotech Research and Development: Research and Development in Biotechnology - Biotechnology and seed policy- Role of Multi-national and Domestic Seed Firms- Moral issues in Patenting Biotechnological inventions- Bio-safety and Bioethics- International bio-safety protocols-cartegena protocols.

IP in Indian Agriculture: Sui-generis system and Status of plant varieties protection in India- Protection of plant genetic resources- protection of Bio-diversity in India-Protection of GIs.

V. Practicals (16 Lectures)

Literature resources: selection and study on a disease, Identification of receptor and ligand involved, search on the drugs at practice, mechanism of their action, toxicity issues-using search engines, Databases on Toxicogenomics- KEGG, chemical databases- Chemfinder, ADME databases, Identification of pharmacophores using databases- retrieving their properties, structure in Smiles notation using Pubchem/ drug bank. Conversion of SMILES, SYBYL, MOL files to PDB format- CORINA, conversion of coordinate file to topology formats- prodrg server, Small molecule generation, evaluation and optimization using Chemsketch, Comparative gene expression analysis on normal and diseased condition, A study on ADME properties-ADME database, calculation of ADME properties- Lipinski rule – Molinspiration tool, High throughput assay to determine a drug toxic effect- ADMEtox, Structural analysis of Protein and Pharmacophores; structural alignment, structural properties-Rasmol/SPDBV, Study of instruments used in experimental Pharmacology, smoking and fixing a kymograph - Handling of laboratory animals - Techniques of drug administrations in animals - Influence of route of administration of drugs on drug response.

VI. Suggested Reading

- Qing Yan. 2006. *Pharmacogenomics in Drug Discovery and Development*. Humana press.
- Licinio, J., and Wong, M.L. 2002. *Pharmacogenomics: The Search for Individualized Therapies*. Wiley-VCH,Verlag GmbH.
- Burcznski, M. E. 2003. *An Introduction to Toxicogenomics*. CRC press.
- Catania MG. 2005. *An A-Z Guide to Pharmacogenomics*, AACC Press.
- Kille P. 2008. *Comparative Toxicogenomics*. Christer Hogstrand. Elsevier Science
- Erbisch FH and Maredia K. 1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
- Anonymous. 2004. *State of Indian Farmer*. Vol. V. Technology, Ministry of Agriculture, Government of India.

- Rothschild M and Scott N. (Ed.). 2003. *Generation and IPR Issues*. Academic Foundation.
- B.L.Wadera. 1996. *Patents, Trade Marks, Copy Right Designs & Geographical Indications*. Universal Law Publishing Co.Pvt.Ltd.
- Narayana PS. 2004. *Intellectual Property Law in India*. K.C.Gogia ,M/S Gogia Law Publication.
- Ganguli P. 2008. *Intellectual Property Rights: Unleashing Knowledge Economy*, McGraw Hill, New Delhi
- Santaniello V, Evenson RE, Zilberman D, Carlson GA. 2000. *Agriculture and Intellectual Property Rights: Economic, Institutional and Implementation Issues in Biotechnology*, CABI Publishing, Wallingford, UK

I. Course Title : Biological Data Integration and Quality Control

II. Course Code : BI 609

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize the techniques of data sources, data curation and integration of data sources

Unit I (5 Lectures)

Curation of genomics, genetic, proteomics, High-throughput screening, array, qPCR data sets; Quality management of data: tools and techniques.

Unit II (6 Lectures)

Biological data sources, Data granularity, Schema modelling, architecture, query design, extraction, transformation and loading, Long term data management, storage and security.

Unit III (5 Lectures)

Bio-chip information system, visualization and reporting, Risk factors for data quality management.

V. Practicals (16 Lectures)

Understanding the data sources, Data granularity, Data modeling and architecture, development of database, Storage, Security, Visualization and reporting.

VI. Suggested Reading

- Kozak, K. 2010. Large Scale Data Handling in Biology. 2010. Ventus Publishing ApS. ISBN 978-87-7681-555-4.
- Harold, E. and Means W.S. 2004. *XML in a Nutshell*, Third Ed. O'Reilly, Sebastopol, CA
- Witten, I.H. and Frank E. 2005. *Data Mining: Practical Machine Learning Tools and Techniques* WEKA, 2nd Ed. San Francisco, Morgan Kaufmann
- Lodish, H. *et al*. 2000. *Molecular Cell Biology*. New York: Freeman & Co.
- Kaneko K. 2006. *Life: An Introduction to Complex Systems Biology*. Springer.

I. Course Title : Quantum Theory and Applications in Biology

II. Course Code : BI 610

III. Credit Hours : 1+1

IV. Aim of the course

This course introduces the concepts of quantum theory with application in molecular biology

V. Theory

Unit I (5 Lectures)

Classical mechanics, Newton, Lagrange and Hamilton's equations, Schrodinger's equation and its complete solution for S.H.O, central force and angular momentum

Unit II (6 Lectures)

Atomic orbital models, the wave equation, molecular orbitals, the LCAO method, the overlap method, coulomb and resonance integrals, the hydrogen molecule, charge distributions, approximate methods

Unit III (5 Lectures)

Absorbance of frequency-specific radiation (photosynthesis), Conversion of chemical energy into motion, Magneto reception in animals, DNA mutation and Brownian motors in many cellular processes

VI. Practicals (16 Lectures)

Classical mechanics, Central force and angular momentum; Atomic orbital model, Wave equation, Resonance integers. DNA mutation and Brownian motors in many cellular processes.

VII. Suggested Reading

- Heisenberg W. 1949. *The Physical Principles of the Quantum T1heory*.
- Bohm D. 1951. *Quantum Theory*.
- Ghatakm AK and Lokanathan S. 2004. *Quantum Mechanics: Theory and Applications.*
- Bittner ER. 2009. *Quantum Dynamics: Applications in Biological and Materials Systems*.
- Blinder SM. 2004. *Introduction to Quantum Mechanics: In Chemistry, Materials Science, and Biology.*

Biotechnology and Bioinformatics
– Molecular Biology and Biotechnology

Executive Summary
(Molecular Biology and Biotechnology)

There has been a surge of knowledge during the past decades in various streams of science and technology applicable to agriculture, attributed largely to growth in the frontier areas of basic sciences. Plant molecular biology is one such area that has evolved rapidly from conventional genetics, cell biology and tissue culture-based knowledge to the present level of precision genomic selection and genome editing technologies. This has been made possible by a deeper understanding of the basic molecular processes, genome organization, evolution and gene expression at molecular, cellular, organ and finally trait level. Explosion of plant genome and transcriptome data over the past two decades has enrichedour understanding of the vast amounts of genetic information present in the plant species and its role in plant growth and development. This is particularly important for agriculture where breaking the yield barrier has become a real challenge with limited availability of genetic resources for biotic and abiotic stress toleranceto face the global climate change. In such a scenario, plant Molecular Biology and Biotechnology assumes great significance as it has shown the potential for development of products and disruptive technologies with far reaching impact on the Indian agriculture.With this background, the present M.Sc. and Ph.D. syllabi for Molecular Biology and Biotechnology (MBB) is designed to acquaint the students with the basic and applied aspects of Plant Biotechnology. The course contents are structured to provide a complete insight in the subject and ignite the young minds with knowledge and wisdom to take up the challenge of research and teaching of modern Plant Biotechnology. The syllabus has now separate course contents for M.Sc.(500 series courses) and Ph.D.(600 series courses) programme, however a Ph.D. student may take some the M.Sc. courses if required to build the basic understanding in an area not studied during his/ her Master's programme. Following are the key features of the revised MBB course curriculum.

- A set of four courses (total 12 credits) including(i) Fundamentals of Molecular Biology, (ii) Molecular Cell Biology, (iii) Omics and Systems Biology and (iv) Techniques in Molecular Biology I now constitute the major 'Core' for the Masters programme. Additional 8 credits from the major subject will be taken as optional courses which will lead to specialization of the student towards functional genomics, molecular breeding or genetic engineering.
- The technique courses are designed to provide hands on exposure in the experimental procedures. This will prime the students with the basic laboratory skills for moving to diverse advance courses that cater to newer and frontier areas of Plant Biotechnology.
- Genomics is now a full-fledged domain consisting of various components. It combines the power of Bioinformatics to provide the necessary thrust for undertaking advance molecular breeding. A course on Omics and Systems Biology has been developed to address diverse areas including ionomics, metabolomics and proteomics.
- GM technology has now captured the public attention with huge societal impact and students need to prepare to understand its potential. The courses have been deigned to include contents on the latest techniques like genome editing for

developing precisiongenetic engineering.

- Climate change has been ravaging the rainfed agriculture for some time now and particularly abiotic stresses like heat, drought, flooding and salinity have assumed greater importance. Hence, a new course on "Stress Biology and Genomics" has been included to provide the students an insight into various approaches for tackling such crisis.
- Another new course on"Gene Regulation" is now part of the syllabus, its content includes various pathways involved in growth and development.
- Biotechnology is skill oriented with great market potential in the agrarian economy. A new course on "Bio-entrepreneurship" has been included to empower the students with basics of business creation, so that the idea of a "Startup" can be taken up at an early stage.
- Lately, RNAs have attracted immense attention as they assume greater significance in gene regulation. Hence, a new course on "RNA Biology" has been added as an advanced course to provide insights into potential role of non-coding RNAs in various regulatory pathways.
- Keeping in view the importance of plant hormones a new course on "Plant Hormones and Signaling" has been proposed.
- A course on "Plant Microbe Interaction" has been reintroduced as it is now more relevant under the changing soil and climatic conditions and provide a wealth of information through Metagenomics approaches.
- Genomics is incomplete without Bioinformatics and a new advanced course on "Computational and Statistical tools in Biotechnology" has been introduced in the doctorate program.
- Courses on Animal biotechnology have been dropped for providing a focused content exclusive to Plant Biotechnology.

Preamble

Development of cutting-edge technologies and skilled human resource is the need of the hourto put the country's agricultural growth on fast track. Biotechnology one such area which is essentially interdisciplinary in nature incorporating genetics, biochemistry, molecular biology, microbiology, immunology and most recently bioinformatics. It is based on techniques dealing with genes, genomes, nucleic acids and other related macro and micro biomolecules. Agricultural Biotechnology is a rapidly evolving branch of science that is expanding exponentially as an advanced interdisciplinary technology with immense application potential for Agriculture. To cite a few successful examples- banana, orchids and date palm cultivations in parts of India has become possible only because of tissue culture generated planting material. Similarly, Bt-cotton has been a commercial success, with new generation of Bt-cotton coming up to tackle emerging problems, genetically modified crops including brinjal, mustard, potato, tomato and maize have also been developed, awaiting regulatory approval for commercialization. Several varieties developed through of marker-assisted breeding have been already released and notified for commercial cultivation, *e.g.* rice varieties Swarna-Sub-1, Improved Samba Mahsuri, Pusa Basmati 1637, Pusa Basmati 1718, DRR Dhan 50, Ranjit-Sub-1, wheat variety Unnat PBW343, super chickpea variety BGM 10216 and so on. With the availability of high-quality reference genomes of many crop plants it is now possible to dissect the genetics of complex agronomic traits in a precise manner and utilize the information for marker-assisted breeding. With advancing gene editing tools,directed genome modification has now become a reality ushering in a new era of precision plant breeding. Thus, rice plants immune to bacterial leaf blight (BLB) disease have been developed by knocking down three sweet genes which are essential susceptibility factors for BLB infection. Other biotechnological applications include disease diagnostics, DNA bar coding for varietal protection, bio-pesticides, bio-fertilizers, crop residue management, bio-ethanol production, cryopreservation, artificial seed production, exploiting apomixis, male sterility and so on. Biotechnology is an emerging discipline with scope for constant innovations made possible by a deeper understanding of the basic molecular and cellular processes including their genetic basis. It is particularly important forthe agriculture sector where breaking the yield barrier is a challenge, and newsources for biotic and abiotic stress tolerance for adaptation to theglobal climate change are limited. In such a scenario, plant molecular biology and biotechnology assumes enormous significance as it has shown the potential for product development with far reaching impact on the Indian agriculture.

The tremendous impetus received for biotechnological research and education has been due to its direct impact on human and animal health, agricultural productivity and environment issues. Due to increasing acceptance of genetically modified foods and agricultural produce, big pharmaceutical and agribusiness companies are investing huge funds in the biotechnology R&D sector. At present in India the number of companies involved in R&D or product development or production related to biotechnology and life sciences products has grown close to 350. The demand for trained workforce in Biotechnology is ever growing in Research and Industry Sectors. Academic and research sectors require interdisciplinary trained human resource to furtherharness the power of biotechnological revolution. The need of the hour is to design appropriate syllabi that keeps pace with changing times and technology with emphasizes on utilization with in depth elucidation of the technology.With this background, the present syllabus for the Molecular Biology and Biotechnology (MBB) discipline was designed to acquaint the students with a basic and modern outlook of plant biotechnology. The course contents hve been structured to provide a complete insight and ignite the young minds with knowledge and wisdom to take up the dual challenge of research and teaching in modern agriculture.

A set of four courses namely Fundamentals of Molecular Biology, Molecular Cell Biology, Omics and Systems Biologyand Techniques in Molecular Biology I with a total of 12 credit hours constitutes the major core. The student will have to take 8 more credits of optional major courses according to their interest in functional genomics, molecular breeding or genetic engineering to complete the required 20 credit hours of major courses. A minor with total 6 credits needs to be taken from any of the related disciplines such as Genetics & Plant Breeding, Biochemistry, Plant Physiology, Microbiology, Plant Pathology, Plant Genetic Resources, Bioinformatics and others. Total 5 credit hours of courses must be taken from of the basic supporting disciplines including Genetics, Biochemistry, Microbiology, Bioinformatics, Computer Applications and Statistics. One credit of seminar and 30 credits of thesis research make up the total 70 credit hours required for the M.Sc. degree programme. Similarly, the credit hour distribution for Ph.D. courses have been revised to give added emphasis on research component as compared to theoretical courses. The overall requirement for Ph.D. programme is 12 credits for major courses (6 credits of core plus 6 credits of optional courses), 6 credits of minor courses from one of the related disciplines, 5 credits for basic supporting courses, 2 credits of seminar and 75 credits of thesis research, making a total of 100 credit hours.

All courses have been revised and new courses have been introduced keeping in view the recent developments in the MBB discipline. The new courses include: (i) **Omics and System biology** to address all the high throughput areas including genomics, transcriptomics, proteomics, metabolomics and ionomics; (ii) **Stress Biology and Genomics** to provide insights into various approaches for tackling climate change induced stresses; (iii) **Gene Regulation** focusing on various pathways of plant growth and development; (iv) **Bio-entrepreneurship** to empower the students with the basic knowledge of the business of Biotechnology; (v) **RNA Biology**to provide deeper insights into the potential role of non-coding RNAs in various regulatory pathways; (vi) **Plant Hormones and Signaling** to get deeper insights into the role of plant hormones; (vii) **Plant Microbe Interactions**to provide a wealth of information through microbial genomics and metagenomics approaches; and (viii) '**Computational and Statistical Tools in Biotechnology**' to cater for the growing need of the knowledge of Bioinformatics in MBB discipline. Animal biotechnology courses have been deleted to provide a focused content exclusive to Plant Biotechnology.

Thus, the present syllabus provides a proper balance of the advance molecular biology and their biotechnological applications.The restructuring of syllabus and courses has been done anticipating the future needs of Biotechnology Sector with more emphasis on imparting practical knowledge and skills. The main thrust was to makeit compatible with the recent developments in new education policy, research and industrial sectors and imparting an skill-set that will contribute to nation building through dissemination of specialized knowledge and skills in Agricultural Biotechnology.

Course Title with Credit Load
M.Sc. in Molecular Biology and Biotechnology

Course Code	Course Title	Credit Hours
	Major: 20 credits	
	(12 credits of core + 8 credits of optional)	
MBB 501	Principles of Biotechnology	3+0
MBB 502	Fundamentals of Molecular Biology*	3+0
MBB 503	Molecular Cell Biology*	3+0
MBB 504	Techniques in Molecular Biology I*	0+3
MBB 505	Omics and Systems Biology*	2+1
MBB 506	Plant Genetic Engineering	3+0
MBB 507	Techniques in Molecular Biology II	0+3
MBB 508	Introduction to Bioinformatics	2+1
MBB 509	Plant Tissue culture	2+1
MBB 510	Microbial and Industrial Biotechnology	2+1
MBB 511	Molecular Plant Breeding	2+1
MBB 512	IPR, Bio-safety and Bioethics	2+0
MBB 513	Immunologyand Molecular Diagnostics	3+0
MBB 514	Nano Biotechnology	2+1
MBB 515	Environmental Biotechnology	3+0
MBB 516	Bio-entrepreneurship#	1+0
MBB 517	Stress Biology and Genomics#	2+0
MBB 518	Gene Regulation#	2+0
	Minor (8 credits) – from one of the related disciplines	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Plant Physiology	
	Plant Pathology	
	Entomology	
	Bioinformatics	
	Plant Genetic Resources	
	Any other related discipline	

Course Code	Course Title	Credits (L+P)
	Basic Supporting (6 credits) from the following disciplines	
	Biochemistry	
	Microbiology	
	Genetics and Plant Breeding	
	Statistics	
	Bioinformatics	
	Computer Applications	
	Common courses	5
MBB	Seminar	0+1
MBB500	Research	0+30
	Total	**70**

*Core Courses; # New Courses

Course Contents
M.Sc. in Molecular Biology and Biotechnology

I. Course Title : Principles of Biotechnology

II. Course Code : MBB 501

III. Credit Hours : 3+0

IV. Aim of the course

- To understand the basics of Molecular biology, plant and microbial Biotechnology
- Importance and applications in agriculture, case studies and success stories
- Public education, perception, IPR and related issues

V. Theory

Unit I (12 Lectures)

History, scope and importance of Biotechnology; Specializations in Agricultural Biotechnology: Genomics, Genetic engineering, Tissue Culture, Bio-fuel, Microbial Biotechnology, Food Biotechnology etc. Basics of Biotechnology, Primary metabolic pathways, Enzymes and its activities.

Unit II (16 Lectures)

Structure of DNA, RNA and protein, their physical and chemical properties. DNA function: Expression, exchange of genetic material, mutation. DNA modifying enzymes and vectors; Methods of recombinant DNA technology; Nucleic acid hybridization; DNA/RNA libraries; Applications of gene cloning in basic and applied research, Plant transformation: Gene transfer methods and applications of GM crops.

Unit III (8 Lectures)

Molecular analysis of nucleic acids -PCR and its application in agriculture and industry, Introduction to Molecular markers: RFLP, RAPD, SSR, SNP etc, and their applications; DNA sequencing, different methods; Plant cell and tissue culture techniques and their applications.Introduction to genomics, transcriptomics, ionomics, metabolomics and proteomics. Plant cell and tissue culture techniques and their applications.

Unit IV (12 Lectures)

Introduction to Emerging topics: Genome editing, gene silencing, Plant microbial interactions,Success stories in Biotechnology, Careers and employment in biotechnology. Public perception of biotechnology; Bio-safety and bioethics issues; Intellectual property rights in biotechnology.

VI. Suggested Reading

- Watson JD, Baker TA, Bell SP, Gann A, Levine M and Losick R. 2014. *Molecular Biology of the Gene*, 7th edition, Cold Spring Harbor Laboratory Press, New York
- Brown T A. 2010. *Gene Cloning and DNA analysis an Introduction* 6th edition, Wiley Blackwell
- Primrose SB and Twyman R. 2006. *Principles of gene Manipulation* 7th edition, Wiley Blackwell

- Singh BD. 2012. *Biotechnology: Expanding Horizons* 4th edition, Kalyani publisher, New Delhi, India

I. Course Title : Fundamentals of Molecular Biology

II. Course Code : MBB 502

III. Credit Hours : 3+0

IV. Aim of the course

- To understand the basics of DNA, RNA, structure, types and chromatin assembly.
- To get insights into the Central Dogma, basic cellular processes, role of mutation and recombination.
- To understand different levels of gene regulation and the pathways involved.

V. Theory

Unit I (8 Lectures)

Historical developments of molecular biology, Nucleic acids as genetic material, Chemistry and Nomenclature of nucleic acids; Structure of DNA: primary structure; secondary structure, Forms of DNA: A,B, Z and their function; Structure andTypes of RNA Genome organization in prokaryotes and eukaryotes; DNA Topology; DNA re-association kinetics, Types of repeat sequences.

Unit II (10 Lectures)

Central dogma of Molecular Biology; DNA replication- Classical experiments, Models of DNA replication; DNA replication, Origin and Steps in DNA replication - initiation, elongation and termination; Enzymes and accessory proteins and its mechanisms; Eukaryotic DNA replication in brief. Types of DNA damages and mutations; DNA repair mechanisms, Recombination: Homologous and non-homologous, Genetic consequences.

Unit III (8 Lectures)

Prokaryotic transcription, initiation, elongation and termination, promoters, Structure and function of eukaryotic RNAs and ribosomal proteins. Eukaryotic transcription – RNA polymerase I, II and III, Elongation and Termination, Eukaryotic promoters and enhancers, Transcription factors,Post transcriptional processing, Splicing: Catalytic RNAs, RNA stability and transport, RNA editing.

Unit IV (10 Lectures)

Genetic code and its characteristics,Universal and modified genetic code and its characteristics,Wobble hypothesis; Translational machinery; Ribosomes in prokaryotes and Eukaryotes. Initiation complex formation, Cap dependent and Cap independent initiation in eukaryotes,Elongation: translocation,transpeptidation and termination of translation; Co- and Post-translational modifications of proteins; Translational control; Protein stability -Protein turnover and degradation.

Unit V (12 Lectures)

Gene regulation in prokaryotes, Constitutive and Inducible expression, small molecule regulators; Operon concept: *lac* and *trp* operons, attenuation, anti-termination, stringent control.Gene regulation in eukaryotes– regulatory RNA and RNA interference mechanisms,Silencers, insulators, enhancers, mechanism of silencing and activation; Families of DNA binding transcription factors: Helix-turn-helix, helix-loop-helix etc. Epigenetic regulations

VI. Suggested Reading

- Nelson DL and Cox M.M. 2017. *Lehinger's Principles of Biochemistry*, 7th edition, W H Freeman Publication New York.
- Krebs, J.E., Goldstein, E.S., Kilpatrick, S.T. 2017. *Lewin's Genes* XII 12th edition, Jones & Bartlett Learning publisher, Inc.
- Watson, J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M and Losick R. 2014. *Molecular Biology of the Gene*, 7th edition, Cold Spring Harbor Laboratory Press, New York.
- Alberts, B. 2017. *Molecular Biology of the Cell* 5th edition, WW Norton & Co, Inc.
- Allison, L.A. 2011. *Fundamentals of Molecular Biology*. 2nd Edition, John Wiley and Sons.

I. Course Title : Molecular Cell Biology

II. Course Code : MBB 503

III. Credit Hours : 3+0

IV. Aim of the course

- To understand the basics structure and function of plant and animal cell
- To get insights into the basic cellular processes, transport, signalling, cell movement, cell division and general regulation mechanisms.

V. Theory

Unit I (8 Lectures)

Origin of life, History of cell biology, Evolution of the cell: endo-symbiotic theory, treeof life, General structure and differences between prokaryotic and eukaryotic cell; Similarities and distinction between plant and animal cells; different kinds of cells inplant and animal tissues.

Unit II (8 Lectures)

Cell wall, cell membrane, structure and composition of bio-membranes, Structure and function of major organelles: Endoplasmic reticulum Ribosomes, Golgi apparatus, Mitochondria, Chloroplasts, Lysosomes, Peroxisomes, Micro-bodies, Vacuoles, Nucleus, Cyto-skeletal elements.

Unit III (12 Lectures)

Membrane transport; Diffusion, osmosis, ion channels, active transport, mechanism of protein sorting and regulation of intracellular transport, transmembrane and vesicular transport - endocytosis and exocytosis; General principles of cell communication: hormones and their receptors,signaling through G-protein coupled receptors, enzyme linked receptors; signal transduction mechanisms and regulation, Cell junctions, Cell adhesion, Cell movement; Extracellular matrix.

Unit IV (10 Lectures)

Chromatin structure, Cell division and regulation of cell cycle; Mechanisms of cell division, Molecular eventsat M phase, mitosis and cytokinesis, Ribosomes in relation to cell growth and division, Extracellular and intracellular Control of Cell Division; abnormal cell division: cancer- hall marks of cancer and role of oncogenes and tumor suppressor genes in cancer development - Programmed cell death (Apoptosis).

Unit V (10 Lectures)

Morphogenetic movements and the shaping of the body plan, Cell diversification, cellmemory, cell determination, and the concept of positional values; Differentiated cells and the maintenance of tissues and organ development; Stem cells: types and applications; Basics of Animal development in model organisms (*C. elegans*; *Drosophila*); Plant development.

VI. Suggested Reading

- Alberts, B. 2017. *Molecular Biology of the Cell* 5th edition, WW Norton & Co, Inc.
- Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A., Martin, K.C., 2016. *Molecular Cell Biology* 8th Edition. W.H. Freeman & Co. New York.
- Alberts, B., Bray, D., Lewis, J., Raff, M., Roberts, K., Hopkin, K., Johnson, A., Walter, P., 2013 *Essential of Cell Biology*, WW Norton & Co, Inc.
- Cooper, G.M. and Hausman, R.E. 2013. *The cell: A Molecular Approach* 6th edition, Sinauer Associates, Inc.

I. Course Title : Techniques in Molecular Biology I

II. Course Code : MBB 504

III. Credit Hours : 0+3

IV. Aim of the course

- To get a basic overview of molecular biology techniques, good lab practices and recombinant DNA technology
- To get a hands on training in chromatography, protein analysis, nucleic acid analysis, bacterial and phage genetics

V. Practicals

- Good lab practices, preparation of buffers and reagents.
- Principle of centrifugation and spectrophotometry.
- Growth of bacterial culture and preparation of growth curve, Isolation of Genomic DNA from bacteria.
- Isolation of plasmid DNA from bacteria.
- Growth of lambda phage and isolation of phage DNA.
- Isolation and restriction of plant DNA (e.g. Rice / Moong / Mango / Merigold).
- Quantification of DNA by (a) Agarose Gel electrophoresis and (b) Spectrophotometry
- PCR using isolated DNA.
- PAGEGel electrophoresis.
- Restriction digestion of plasmid and phage DNA, ligation, Recombinant DNA construction.
- Transformation of *E. coli* and selection of transformants
- Chromatographic techniques
  a. TLC
  b. Gel Filtration Chromatography,
  c. Ion exchange Chromatography,
  d. Affinity Chromatography
- Dot blot analysis, Southern hybridization,Northern hybridization.
- Western blotting and ELISA.
- Radiation safety and non-radio isotopic procedure.

VI. Suggested Reading

- Sambrook, J., and Russell, R.W. 2001. *Molecular Cloning: A Laboratory Manual* 3rd Edition, Cold spring harbor laboratory press, New York.
- Wilson, K., and Walker, J., 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th edition, Cambridge University Press.
- Ausubel FM, Brent R, Kingston RE, Moore DD, Seidman JG, Smith JA and Struhl K. 2002. *Short Protocols in Molecular Biology* 5th edition, Current Protocols publication.

I. Course Title : Omics and Systems Biology

II. Course Code : MBB 505

III. Credit Hours : 2+1

IV. Aim of the course

- To get a basic overview of genomics, proteomics, ionomics and metabolomics
- To get a primary information on the application of omics science across the industry

V. Theory

Unit I (8 Lectures)

Different methods of genome sequencing, principles of various sequencing chemistries, physical and genetic maps, Comparative and evolutionary genomics, Organelle genomics, applications in phylogenetics, case studies of completed genomes, preliminary genome data analysis, basics of ionomics analysis, different methods

Unit II (6 Lectures)

Protein-basics: primary-, secondary- and tertiary structure, Basics of X-ray crystallography and NMR, Principal and Applications of mass spectrometry, Proteomics: Gel based and gel free, Basics of software used in proteomics, MASCOT, PD-Quest, etc., Study of protein interactions, Prokaryotic and yeast-based expression system and purification

Unit III (6 Lectures)

Metabolomics and its applications, Use of 1D/2D NMR and MS in metabolome analysis, Multivariate analysis and identification of metabolite as biomarkers, Study of ionome using inductively coupled plasma – mass spectroscopy (ICP-MS), X-Ray Fluorescence (XRF), Neutron activation analysis (NAA), Data integration using genome, transcriptome, proteome, metabolome and ionome with phenome.

Unit IV (6 Lectures)

Introductory systems Biology - The biochemical models, genetic models and systems model, Molecules to Pathway, Equilibrium binding and cooperatively – Michaelis-Menten Kinetics, Biological oscillators, Genetic oscillators,Quorum Sensing, Cell-cell communication, *Drosophila* Development, Pathways to Network, Gene regulation at a single cell level, transcription network, REGULATORY CIRCUITS, Negative and positive auto-regulation, Alternative Stable States, Bimodal Switches, Network building and analysis

VI. Practical (12)

- Isolation of HMW DNA and brief overview of sequencing, Primary information on genome data analysis.
- BSA Standard curve preparation, Extraction of protein and estimation methods.
- Quantification of proteins from different plant tissues using spectrophotometry.
- 2-D Gel Electrophoresis, 2-D Image analysis.
- Experiments on protein-protein interaction (Yeast 2-hybrid, Split Ubiquitin system).
- Demonstration on MALDI-TOF.
- Demonstration on ICP-MS, AAS, Nitrogen estimation using various methods.

VII. Suggested Reading

- Primrose, S.B. and Twyman, R. 2006. *Principles of Gene Manipulation* 7th edition, Wiley Blackwell
- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press.

I. Course Title : Plant Genetic Engineering

II. Course Code : MBB 506

III. Credit Hours : 3+0

IV. Aim of the course

- To get a basic overview of molecular cloning, vectors and genomic library construction.
- To get anoverview of PCR and its applications, sequencing, gene knockouts, transgenics etc.

V. Theory

Unit I (10 Lectures)

Historical background, Restriction Enzymes; DNA Modifying enzymes, ligase, T4 DNA polymerase, Polynucleotide kinaseetc, Cohesive and blunt end ligation; Labeling of DNA: Nick translation, Random priming, Radioactive and non-radioactive probes, Hybridization techniques: Northern, Southern and Colony hybridization, Fluorescence in situ hybridization; Chromatin Immunoprecipitation; DNA-Protein Interactions: Electromobility shift assay.

Unit II (14 Lectures)

Plasmids; Bacteriophages; M13, Phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Animal Virus derived vectors-SV-40; Expression vectors; pMal,pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag, etc.; Baculovirus vectors system, Plant based vectors, Ti and Ri plasmids as vectors, Yeast vectors, Shuttle vectors. Transformation; Construction of libraries; Isolation of mRNA and total RNA; cDNA and genomic libraries; cDNA and genomic cloning, Jumping and hopping libraries, Protein-protein interactive cloning and Yeast two hybrid system; Phage display; Principles in maximizing gene expression; Codon optimization for heterologous expression. Introduction of DNA into mammalian cells; Transfection techniques

Unit III (12 Lectures)

Principles of PCR, Primer design,DNApolymerases, Types of PCR – multiplex, nested, reverse transcriptase, real time PCR, touchdown PCR, hot start PCR, colony PCR, cloning of PCR products; T- vectors; Applications of PCR in gene recombination, Site specific mutagenesis, in molecular diagnostics; Viral and bacterial detection; Mutation detection: SSCP, DGGE, RFLP, Oligo Ligation Assay.

Unit IV (12 Lectures)

Genetic transformation of plants: DNA delivery – *Agrobacterium* mediated method. Direct DNA delivery – chemical mediated electroporation and particle bombardment. Vectors and transgene design - Promoters and Marker genes. Chloroplast transformation. Development of marker-free plants. Analysis of transgenic plants – molecular and Biochemical assays, genetic analysis - Identification of gene integration site - Advance methods – *cis* genesis, intragenesis and targeted genome modification – ZFN, TALENS and CRISPR. Application of transgenic technology.

VI. Suggested Reading

- Brown, T.A. 2010. *Gene Cloning and DNA Analysis an Introduction.* 6th edition, Wiley Blackwel.
- Primrose, S.B. and Twyman, R. 2006. *Principles of Gene Manipulation* 7th edition, Wiley Blackwell.
- Sambrook, J., and Russell, R.W. 2001. *Molecular cloning: A laboratory manual* 3rd Edition, Cold spring harbor laboratory press, New York.
- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press.

I. Course Title : Techniques in Molecular Biology II

II. Course Code : MBB 507

III. Credit Hours : 0+3

IV. Aim of the course

- To get a basic overview of molecular biology techniques, good lab practices and molecular markers.
- To get a hands on training in RNAi, microarrays, yeast2 hybrid and immunological techniques.

V. Practicals

Construction of gene libraries (cDNA and Genomics).

- Synthesis and cloning of cDNA.
- Real time PCR and interpretation of data.
- Molecular markers
  - i. RAPD.
  - ii. SSR.
  - iii. AFLP / ISSR and their analysis.
- Case study of SSR markers - construction of linkage map.
- QTL analysis using genotypic data based on SSR.
- SNP identification and analysis.
- Microarray studies and use of relevant software.
- Proteomics
  - i. 2D gels,
  - ii. Mass spectrometry
- RNAi - designing of construct, phenotyping of the plant.
- Yeast 1 and 2-hybrid interaction.
- Generation and screening of mutants.
- Transposon mediated mutagenesis.
- Immunology and molecular diagnostics: Ouchterlony double diffusion, Immunoprecipitation, Radiation Immunodiffusion, Immunoelectrophoretic, Rocket Immunoelectrophoretic, Counter Current Immunoelectrophoretic,ELISA, Latex Agglutination, Immunohistochemistry.

VI. Suggested Reading

- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press
- Bonifacino, J. S., Dasso, M., Harford, J. B., Liipincott-Schwartz, J., and Yamada, K. M. 2004. *ShortProtocols in Cell Biology*. John Wiley & Sons, New Jersey

- Hawes, C., and Satiat-Jeunemaitre, B. 2001. *Plant Cell Biology: Practical Approach*. Oxford University Press, Oxford
- Sawhney, S.K., Singh, R. 2014. *Introductory Practical Biochemistry*, Alpha science international limited

I. Course Title : Introduction to Bioinformatics

II. Course Code : MBB 508

III. Credit Hours : 2+1

IV. Aim of the course

- To get a basic overview of computational techniques related to DNA, RNA and protein analysis.
- To get a hands on training in software's and programs used to analyse, assemble or annotate genomes, phylogenetics, proteomics etc.

V. Theory

Unit I (8 Lectures)

Bioinformatics basics, scope and importance of bioinformatics; Biological databases for DNA and Protein sequences -PIR, SWISSPROT, GenBank, DDBJ, secondary database, structural databases –PDB,SCOP and CATH, Specialized genomic resources, Microarray database.

Unit II (10 Lectures)

Bioinformatics Tools Facilitate the Genome-Wide Identification of Protein-Coding Genes, Sequence analysis, Sequence submission and retrieval system-SEQUIN, BANKit, SAKURA, Webin, Sequence alignment, pair wise alignment techniques, multiple sequence alignment; Tools for Sequence alignment- BLAST and its variants; Phylogenetic analysis- CLUSTAL X, CLUSTAL W, Phylip, Tcoffee

Unit III (10 Lectures)

Sequencing of protein; Protein secondary structure prediction- Chousfasman, GOR Method, Protein 3DStructure Prediction: Evaluation of models- Structure validation and refinement - Ramachandran plot, Force field calculations, SAVES. Protein function prediction- sequence and domain based, Primer designing- principles and methods.Drug discovery**,** Structure Based Drug Design- Rationale for computer aided drug designing, basic principles, docking, QSAR.

VI. Practical (12 Lectures)

- Usage of NCBI resources
- Retrieval of sequence/structure from databases and submission
- Different Databases, BLAST exercises.
- Assembly of DNA and RNA Seq data
- Annotation of assembled sequences,Phylogenetics and alignment
- Visualization of structures, Docking of ligand receptors
- Protein structure analysis and modeling

VII. Suggested Reading

- Attwood, T.K., and Parry-Smith, D. J. 2004. *Introduction to Bioinformatics*, Pearson Education (Singapore) Pvt. Ltd.
- David Edwards (Ed.) 2007. *Plant Bioinformatics: Methods and Protocols*. Humana Press, New Jersey, USA.

- Mount, D.W. 2004. *Bioinformatics: Sequence and Genome Analysis*. 2nd Revised edition Cold Spring Harbor Laboratory Press, U.S.
- Pevsner J. 2009. *Bioinformatics and Functional Genomics*, 2nd edition, Wiley-Blackwell.

I. Course Title : Plant Tissue Culture

II. Course Code : MBB 509

III. Credit Hours : 2+1

IV. Aim of the course

- To provide insight into principles of plant cell culture and genetic transformation.
- To get a hands on training in basic plant tissue culture techniques, callusing, micropropagation and analysis.

V. Theory

Unit I (12 Lectures)

History of plant tissue culture, principle of Totipotency; Tissue culture media; Plant hormones and morphogenesis; Direct and indirect organogenesis; Direct and indirect somatic embryogenesis; Applications of planttissueculture; National certification and Quality management of TC plants; Genetic Fidelity testing and Virus indexing methods – PCR, ELISA

Unit II (12 Lectures)

Micropropagation of field and ornamental crops; Virus elimination by meristem culture, meristemtip culture and micrografting; Androgenesis and gynogenesis - production of androgenic and gynogenic haploids - diploidization; Protoplast culture - isolation and purification; Protoplast culture; Protoplast fusion; Somatic hybridization - Production of Somatic hybrids and Cybrids;, Wide hybridization - embryo culture and embryo rescuetechniques; Ovule, ovary culture and endosperm culture.

Unit III (12 Lectures)

Large-scalecell suspension culture - Production of alkaloids and other secondary metabolites- techniques to enhance secondary metabolite production, Somaclonal and gametoclonal variations – causes and applications; Callus culture and *in vitro* screening for stress tolerance; Artificial seeds, *In vitro* germplasm storage and cryo-preservation. Commercial Tissue Culture: Case studies and success stories, Market assessment; project planning and preparation, economics, government policies

VI. Practical (12)

- Preparation of stocks - macronutrients, micronutrients, vitamins and hormones, filter sterilization of hormones and antibiotics. Preparation of Murashige and Skoog medium.
- Micro-propagation of plants by nodal and shoot tip culture.
- Embryo culture to overcome incompatibility, Anther culture for haploid production.
- Callus induction in tobacco leaf discs, regeneration of shoots, root induction, role of hormones in morphogenesis.
- Acclimatization of tissue culture plants and establishment in greenhouse.
- Virus indexing in tissue culture plants. (Using PCR and ELISA).
- Plan of a commercial tissue culture unit.

VII. Suggested Reading

- Razdan, M.K. 2003. *Introduction to plant tissue culture*, 2nd edition, Oxford publications group
- Butenko, R.G. 2000. *Plant Cell Culture* University Press of Pacific
- Herman, E.B. 2008. *Media and Techniques for Growth, Regeneration and Storage*, Agritech Publications, New York, USA.
- Bhojwani, S.S and Dantu P. 2013. *Plant Tissue Culture – An Introductory Text*. Springer Publications.
- Gamborg, O.L and G.C. Philips (eds.). 2013. *Plant Cell, Tissue and Organ culture-Lab Manual*. Springer Science & Business media.

I. Course Title : Microbial/ Industrial Biotechnology

II. Course Code : MBB 510

III. Credit Hours : 2-+1

IV. Aim of the course

To familiarize about the various microbialprocesses/systems/activities, which have been used for the development of industrially important products/processes.

V. Theory

Unit (8 Lectures)

Introduction, scope and historical developments; Isolation, screening and genetic improvement (involving classical approaches) of industrially important organisms.

Unit II (8 Lectures)

Primary metabolites, production of industrial ethanol as a case study; Secondary metabolites, bacterial antibiotics and non-ribosomal peptide antibiotics as case study; Recombinant DNA technologies for microbial processes; Strategies for development of industrial microbial strains with scale up production capacities; Metabolic pathway engineering of microbes for production of novel product for industry.

Unit III (8 Lectures)

Microbial enzymes, role in various industrial processes, production of fine chemicals for pharmaceutical industries; Bio-transformations, Bio- augmentation with production of vitamin C as a case study; Bioreactors, their design and types; Immobilized enzymes-based bioreactors; Microencapsulation technologies for immobilization of microbial enzymes.

Unit IV (8 Lectures)

Environmental Biotechnology, biotreatment for pollution control, treatment of industrial and other wastes, biomass production involving single cell protein; Bio-remediation of soil; Production of eco-friendly agricultural chemicals, bio- pesticides, bio-herbicides, bio-fertilizers, bio-fuels, etc.

VI. Practical

- Isolation of industrially important microorganisms, their maintenance and improvement.
- Lab scale production of industrial compounds such as alcohol, beer, citric acid, lactic acid and their recovery.
- Study of bio-reactors and their operations.
- Production of bio-fertilizers.
- Experiments on microbial fermentation processofantibiotics, bio-pigments, dairy products,

harvesting purification and recovery of end products.
- Immobilization of cells and enzymes, studies on its kinetic behavior, growth analysis and biomassestimation.
- Determination of mass transfer coefficient.

VII. Suggested Reading

- Waites, M.J., Morgan, N.L., Rockey, J.S., Higton, G. 2001. *Industrial Microbiology: An Introduction*, Wiley-Blackwell.
- Slater, A., Scott, N.W., & Fowler, M.R. 2003. *The Genetic Manipulation of Plants. Plant Biotechnology Oxford, England: Oxford University Press*.
- Kun, L.Y. (Ed.). 2003. *Microbial biotechnology: principles and applications*. World Scientific Publishing Company.

I. Course Title : Molecular Plant Breeding
II. Course Code : MBB 511
III. Credit Hours : 2-+1

IV. Aim of the course

- To familiarize the students about the use of molecular biology tools in plant breeding.
- To provide a hands on training in data analysis, diversity analysis and mapping of genes and QTLs.

V. Theory

Unit I (8 Lectures)

Inheritance of qualitative and quantitative traits. Heritability – its estimation, Population structure of self- and cross-pollinated species, Factors affecting selection efficiency. Development of different kinds of segregating populations – F_2, F_3, BC_1F_1, BC_1F_2, BC_4F_2, RIL (Recombinant Inbred Lines), AIL (Advanced Intercrossed Lines), DH (Di-haploid population), NIL (Near Isogenic lines), NAM (Nested Association Mapping), MAGIC (Multi-parent Advanced Generation Intercross population).

Unit II (8 Lectures)

Causes of sequence variation and its types, Types of molecular markers and development of sequence based molecular markers – RFLP, AFLP, SCARs, CAPS, SSRs, STMS, SNPsInDel and DARTseq; Inheritance of markers, Linkage analysis using test cross, F_2, F_3, BC_1F_1, RIL. Construction of genetic map, Mapping genes for qualitative traits; Genotyping by sequencing and high-density chip arrays.

Unit III (8 Lectures)

QTL mapping using structured populations; Association mapping using unstructured populations; Genome Wide Association Studies (GWAS),Principle of Association mapping– GWAS-SNP genotyping methods, DART array sequencing, Illumina's Golden Gate Technology, Genotyping by sequencing methods- Fluidigm; GBS, Illumina Hi seq- Nano pore sequencing, Principles and methods of Genomic Selection, Fine mapping of genes/QTL; Development of gene based markers; Allele mining by TILLING and Eco-TILLING.

Unit IV (8 Lectures)

Tagging and mapping of genes. Bulk segregant and co-segregation analysis, Marker assisted selection (MAS); Linked, unlinked, recombinant, flanking, peak markers. Foreground and background selection; MAS for gene introgression and pyramiding: MAS for specific traits with examples. Haplotype concept and Haplotype-based breeding; Genetic variability and DNA fingerprinting. Molecular markers in Plant variety protection, IPR issues, hybrid purity testing, clonal fidelity testing and transgenic testing.

VI. Practical

- Construction of linkage map.
- QTL analysis using the QTL cartographer and other software.
- SNP data analysis using TASEEL.
- Detection of haplotype block using SNP data - pLinksoftware.
- Genotyping by sequencing methods –Illumina genotyping platform.
- Marker assisted breeding – MABB case studies quality traits in rice/maize.
- Genome Assisted Breeding in model crops, Genomic Selection models usingthe morphological and SNP data

VII. Suggested Reading

- Acquaah, G. 2007. *Principles of Plant Genetics and Breeding*, Blackwell Publishing Ltd. USA.
- Weising, K., Nybom, H., Wolff, K., and Kahl, G. 2005. *DNA Fingerprinting in Plants: Principles, Methods and Applications*, 2nd ed. Taylor and Francis Group, Boca Raton, FL.
- Halford, N. 2006. *Plant Biotechnology-Current and future applications of genetically modified crops*, John Wiley and Sons, England.
- Singh, B. D. and Singh, A. K. 2015. *Marker-Assisted Plant Breeding: Principles and Practices* Springer (India) Pvt. Ltd.

5. Boopathi, NM. 2013. *Genetic Mapping and Marker Assisted Selection: Basics, Practice and Benefits*. Springer India. p293.

I. Course Title : IPR, Bio-safety & Bioethics

II. Course Code : MBB 512

III. Credit Hours : 2+0

IV. Aim of the course

- To familiarize the students about ethical and biosafety issues in plant biotechnology.
- To provide a hands-on training in data analysis, diversity analysis and mapping of genes and QTLs.

V. Theory

Unit I (10 Lectures)

IPR: historical background in India; trade secret; patent, trademark, design& licensing; procedure for patent application in India; Patent Cooperation Treaty (PCT); Examples of patents in biotechnology-Case studies in India and abroad; copyright and PVP; Implications of IPR on the commercialization of biotechnology products, ecological implications; Trade agreements- The WTO and other international agreements, and Cross border movement of germplasms.

Unit II (8 Lectures)

Biosafety and bio-hazards; General principles for the laboratory and environmental bio-safety; Biosafety and risk assessment issues; handling and disposal of bio-hazards; Approved regulatory laboratory practice and principles,The Cartagena

Protocol on biosafety; Biosafety regulations in India; national Biosafety Policy and Law; Regulations and Guidelines related to Biosafety in other countries

Unit III (8 Lectures)

Potential concerns of transgenic plants – Environmental safety and food and feed safety. Principles of safety assessment of Transgenic plants – sequential steps in risk assessment. Concepts of familiarity and substantial equivalence. Risk - Environmental risk assessment – invasiveness, weediness, gene flow, horizontal gene transfer, impact on non-target organisms; food and feed safety assessment – toxicity and allergenicity.Monitoring strategies and methods for detecting transgenics.

Unit IV (6 Lectures)

Field trails – Biosafety research trials – standard operating procedures, labeling of GM food and crop,Bio-ethics- Mankind and religion, social, spiritual & environmental ethics; Ethics in Biotechnology, labeling of GM food and crop; Biopiracy

VI. Suggested Reading

- Goel, D. and Parashar, S. 2013. *IPR, biosafety, and bioethics*.
- Joshi, R. 2006. *Biosafety and Bioethics*.
- Nambisan, P. 2017. *An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology*.

I. Course Title : Immunology and Molecular Diagnostics

II. Course Code : MBB 513

III. Credit Hours : 3+0

IV. Theory

Unit I (6 Lectures)

Immunity and its classification; Components of innate and acquired immunity; Lymphatic system; Hematopoiesis; Organs and cells of the immune system- primary, secondary and tertiary lymphoid organs Descriptions of Antigens - immunogens, hapten and adjuvants.

Unit II (12 Lectures)

Immunoglobulins-basic structure, classes & subclasses of immunoglobulins, antigenic determinants; Multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; Principles of cell signaling; Basis of self and non-selfdiscrimination; Kinetics of immune response, memory; B cell maturation, activation and differentiation; Generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; Functional T Cell Subsets; Cell-mediated immune responses, ADCC; Cluster of Differentiations (CDs), Cytokines-properties, receptors and therapeutic uses.

Unit III (8 Lectures)

Phagocytosis; Complement and Inflammatory responses; Major Histocompatibility Complex - MHC genes, MHC and immune responsiveness and disease susceptibility, HLA typing; Antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; Cell-cell co-operation, Hapten-carrier system

Unit IV (10 Lectures)

Precipitation, agglutination and complement mediated immune reactions; Advanced immunological techniques – RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; Surface plasmon resonance, Biosenor assays for assessing ligand –receptor interaction, CMI techniques- lymphoproliferation assay, Mixed lymphocyte reaction, Cell Cytotoxicity assays, Apoptosis, Transgenic mice, Gene knock outs

Unit V (12 Lectures)

Active and passive immunization; Live, killed, attenuated, sub unit vaccines; Vaccine technology- Role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, Antibody genes and antibody engineering- chimeric and hybrid monoclonal antibodies, Immunity to Infection,Bacteria, viral, fungal and parasitic infections, Hypersensitivity – Type I-IV; Autoimmunity; Types of autoimmune diseases, MHC and TCR in autoimmunity; Transplantation, Immunological basis of graft rejection, immunosuppressive therapy; Tumor immunology – Tumor antigens.

V. Suggested Reading

- Owen J.A., Punt, J., & Stranford, S. A. 2013. *Kuby immunology* (p. 692). New York: WH Freeman.
- Kenneth, M., and Weaver, C. 2017. *Janeways Immunobiology*, 9th Edition, New York, USA: Garland Science, Taylor & Francis publisher.
- William, P. 2013. *Fundamental of Immunology*, 7th edition, Lippencott, William and Wilkins publisher.

I. Course Title : Nano Biotechnology

II. Course Code : MBB 514

III. Credit Hours : 2+1

IV. Aim of the course

Understanding the molecular techniques involved in structure and functions of nano-biomolecules in cells such as DNA, RNA and proteins.

V. Theory

Unit I (8 Lectures)

Introduction to Nanotechnology - Nanomaterials - Self-assembly to artificial assembly for creation of useful nanostructures – Bottoms up and Top down approach (Nano rods, nano cages, nanotubes, quantum dots, nanowires, metal/ polymer-based nanostructures) – Preparation and Characterization of nanoparticles (particle size analyzer, microscopy, viz. electron microscopy, atomic force microscopy, etc).

Unit (8 Lectures)

Cell structure – Bio macromolecules: Types, Structure, Dynamics and interaction with water – Cellular nano machines – cellular transducers, membrane channels, membrane transporters, Membrane motors – Creation of bio-nanostructures (Nano liposomes, Nano micelles, Nanomotors, etc).

Unit III (8 Lectures)

Chemical, physical and biological properties of biomaterials and bio response: biomineralization, biosynthesis, and properties of natural materials (proteins, DNA, and polysaccharides), structure-property relationships in polymeric materials (synthetic polymers and structural proteins); Aerosol properties, application and dynamics; Statistical Mechanics in Biological Systems,

Unit (8 Lectures)

Nanoparticular carrier systems; Micro- and Nano-fluidics; Drug and gene delivery system; Microfabrication, Biosensors, Chip technologies, Nano- imaging, Metabolic engineering and Gene therapy.

VI. Practical

- Isolation of enzymes and nucleic acids involved in biosynthesis of nanomaterials
- Synthesis of Gold/silver Nanoparticles by biogenic methods, Synthesis of micelles and inverse micelles
- Synthesis of Carbon Nano-materials by Chemical Vapor Deposition and Sputtering technique
- Preparation ofthiolate silver nanoparticles, Purification and measurement of carbon nano materials
- Zinc selenide quantum dot preparation, Synthesis of Iron Oxide Nanoparticle
- Thin film preparation by spin coating technique, Synthesis of Nickel metal nanoparticle by urea decomposition method
- Synthesis of Zinc Oxide nanoparticle

VII. Suggested Reading

- Nalwa, H.S. 2005. *Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology*. American Scientific Publications.
- Niemeyer C.M. and Mirkin C.A. (Eds) 2005. *Nanobiotechnology: Concepts Applications and Perspectives,* Wiley Inter-science publications.
- Cao, G., and Wang, Y. 2004. *Nanostructures and Nanomaterials: Synthesis, Properties and Applications*, Imperial College Press.

I. Course Title : Environmental Biotechnology

II. Course Code : MBB 515

III. Credit Hours : 3+0

IV. Aim of the course

To apprise the students about the role of biotechnology in environment management for sustainable eco-system and human welfare.

V. Theory

Unit I (8 Lectures)

Basic concepts and environmental issues; types of environmental pollution; problems arising from high-input agriculture; methodology of environmental management; air and water pollution and its control; waste water treatment - physical, chemical and biological processes; need for water and natural resource management.

Unit II (8 Lectures)

Microbiology and use of micro-organisms in waste treatment; biodegradation; degradation of Xenobiotic, surfactants; bioremediation of soil & water contaminated with oils, pesticides and toxic chemicals,detergentsetc; aerobic processes (activated sludge, oxidation ditches, trickling filter, rotating drums, etc); anaerobic processes: digestion, filtration, etc.

Unit III (8 Lectures)

Renewable and non-Renewable resources of energy; energy from solid waste; conventional fuels and their environmental impact; biogas; microbial hydrogen production; conversion of sugar to alcohol; gasohol; biodegradation of lignin and cellulose; biopesticides; biofertilizers; composting; vermiculture etc.

Unit IV (8 Lectures)

Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by microorganisms; global environmental problems: ozone depletion, UV-B, greenhouse effects, and acid rain; biodiversity and its conservation; biotechnological approaches for the management environmental problems.

VI. Suggested Reading

- Evans, G. M. and Furlong, J. C. 2010. *Environmental Biotechnology: Theory and Application*. 2nd edition, Wiley-Blackwell.
- Jordening HJ and Winter J. 2006. *Environmental Biotechnology: Concepts and Applications*. Wiley-VCH Verlag.

I. Course Title : Bio-entrepreneurship

II. Course Code : MBB 516

III. Credit Hours : 1+0

IV. Aim of the course

The objective of this course is to teach students about fundamentals of entrepreneurship, launching a venture or a start up in biotechnology-based theme.

V. Theory

Unit I (4 Lectures)

Scope in biotechnology; types of bio-industries – bio-pharma, bio-agri, bio-services and bio-industrial; Importance of entrepreneurship; introduction to bioentrepreneurship – biotechnology in a global scale; –skills for successful entrepreneur–creativity, leadership, managerial, team building, decision making; opportunities for bio-entrepreneurship- entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Startup & Make in India)

Unit II (4 Lectures)

Business plan preparation; business feasibility analysis by SWOT, socio-economic costs benefit analysis; funds/ support from various agencies; statutory and legal requirements for starting a company/ venture.

Unit III (4 Lectures)

Entry and exit strategy; identifying needs of customers; Market linkages, branding issues; developing distribution channels - franchising; policies, promotion, advertising; branding and market linkages for ‘virtual startup company’. Pricing strategy.

Unit IV (4 Lectures)

Knowledge centers e.g., in universities, innovation centres, research institutions (public & private) and business incubators; R&D for technology development and upgradation; assessment of technology development; managing technology transfer;

VI. Suggested Reading

- Adams, D.J. and Sparrow, J.C. 2008. *Enterprise for Life Scientists: Developing Innovation and Entrepreneurship in the Biosciences*. Bloxham: Scion.
- Shimasaki, C.D. 2014. *Biotechnology Entrepreneurship: Starting, Managing, and Leading Biotech Companies*. Amsterdam: Elsevier. Academic Press is an imprint of Elsevier.
- Onetti, A., and Zucchella, A. 2014. *Business Modeling for Life Science and Biotech Companies: Creating Value and Competitive Advantage with the Milestone Bridge*. Routledge.
- Jordan, J. F. 2014. *Innovation, Commercialization, and Start-Ups in Life Sciences*. London: CRC Press.
- Desai, V. 2009. *The Dynamics of Entrepreneurial Development and Management*. New Delhi: Himalaya Pub. House.

I. Course Title : Stress Biology and Genomics

II. Course Code : MBB 517

III. Credit Hours : 2+0

IV. Aim of the course

To provide advanced knowledge on genomics with reference to abiotic stress tolerance and biotic stress resistance in plants tolerance.

V. Theory

Unit I (10 Lectures)

Different kinds of stresses (biotic and abiotic) and adaptation strategies: Plant cell as a sensor of environmental changes; role of cell membranes in signal perception; Ways of signal transduction in cells and whole plants as a response to external factors.Abiotic stresses affecting plant productivity – Drought, salinity, water logging, temperature stresses, light stress and nutrient stress; Drought stress – Effects on plant growth and development; Components of drought resistance; Physiological, biochemical and molecular basis of tolerance mechanisms; Biotic stress (insect and pathogen) resistance mechanism.

Unit II (12 Lectures)

Strategies to manipulate drought tolerance – Osmotic adjustment and Osmoprotectants - synthesis of proline, glycine betaine, poly amines and sugars; ROS and antioxidants; hormonal metabolism - ABA signaling; signaling components – transcription factors. Water logging stress – effects on plant growth and metabolism; adaptation to water logging,tolerance mechanisms -hormones and flooding tolerance. Strategies for improving submergence tolerance. Salinity stress – effects on physiology and metabolism of plants, SOS pathways and ion homeostasis,Strategies to improve salinity tolerance in plants. Water logging stress – effects on plant growth and metabolism; tolerance mechanisms. Physiological and biochemical changes – High & Low temperature tolerance mechanisms - molecular basis of thermo tolerance. Morphological and physiological changes in plants due to high and low light stresses - photo oxidation -plastid development. Characters of heliophytes and sciophytes – solar tracking – sieve effect and light channeling. Heavy metal stress – Al and Cd stress - effects on plant growth and development, biotech Strategies to overcome heavy metal stress Nutrient stress-effects on plant growth and development. Genetic manipulation strategies to overcome the stress effects.

Unit III (10 Lectures)

Genomics; transcriptomes, small RNAs and epigenomes; functional genomics; transfer of tolerance/resistant genes to model plants and validation of gene function. Different techniques for the functional validation of genes.

Signaling pathway related to defense gene expression, R proteins, RNAi approach and genes from pathogens and other sources, coat protein genes, detoxification genes, transgenic and disease management. Bt proteins, resistance management strategies in transgenic crops, ecological impact of field release of transgenic crops. Bioinformatics approaches to determine gene function and network in model plants under stress.

VI. Suggested Reading

- Buchanan, B.B., Gruissem, W. and Jones R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley and Blackwell Publications.
- Sarwat, M., Ahmad, A., Abdin, M.Z. 2013. *Stress Signaling in Plants: Genomics and Proteomics Perspective*, Volume 1, Springer.
- Heribert Hirt. 2010. *Plant Stress Biology: From Genomics to Systems Biology*, John Wiley.
- Pandey, G.K. 2015. *Elucidation of Abiotic Stress Signaling in Plants*, Stringer.

I. Course Title : Gene Regulation

II. Course Code : MBB 518

III. Credit Hours : 2+0

IV. Aim of the course

To understand the basics of gene regulation including a wide range of mechanisms that are used by organisms to increase or decrease the production of specific gene products in terms of time, space, conditions or their combinations.

V. Theory

Unit I (8 Lectures)

Transcriptional regulation – Regulatory proteins, Activators and Repressors, Binding of RNA polymerase, Allosteric regulation, DNA looping, Cooperative binding, Anti-termination, Combinatorial control – Regulation of *lac, trp* and *ara* Operons. Gene regulation in Lambda phage – lytic or lysogenic establishment.

Unit II (10 Lectures)

Regulatory sequences – Promoters, Enhancers, Silencers, Insulators, Locus Control Region. Activator proteins and their binding sites, DNA binding domain – Homeodomain, Zinc containing proteins, Leucine Zipper Motif, Helix-Loop-Helix, HMG proteins. Recruitment of RNA polymerase to promoter region, Nucleosomes and their modifiers. Signal integration. Signal transduction and transcriptional regulation. Gene Silencing. Epigenetic gene regulation.

Unit III (10 Lectures)

Regulation by RNA in prokaryotes and eukaryotes, RNA as defense agents. Riboswitches. Gene Silencing by RNA - siRNA & miRNA – synthesis and function. Non-coding RNAs their impact, categories and role in gene regulation, chromatin assembly etc.

Unit IV (4 Lectures)

Negative auto-regulation, Positive auto-regulation, Bistable and Bimodal switch, Oscillating pattern of gene expression.

VI. Suggested Reading

- Nelson, D. L. and Cox, M. M. 2017. *Lehinger's Principles of Biochemistry*, 7th edition, W H Freeman Publication New York
- Krebs, J. E., Goldstein, E. S., Kilpatrick, S. T. 2017. *Lewin's Genes* XII 12th edition, Jones & Bartlett Learning publisher, Inc
- Watson, J. D., Baker, T. A., Bell, S. P., Gann, A., Levine,M., & Lonick, R. 2014. *Molecular Biology of the Gene*, 7th Edition, Cold Spring Harbor Laboratory Press, New York.
- Gardner, E. J., Simmons MJ and Snustad, D.P. 2006. *Principles of Genetics* (2006) eighth Edition. Wiley

Course Title with Credit Load
Ph.D in Molecular Biology and Biotechnology

Course Code	Course Title	Credit Hours
	Major: 12 credits (6 credits of core + 6 credits of optional)	
MBB 601	Plant Molecular Biology*	3+0
MBB 602	Plant GenomeEngineering*	3+0
MBB 603	Plant Omics and Molecular Breeding	3+0
MBB 604	Commercial Plant Tissue Culture	2+0
MBB 605	Plant Microbe interaction#	2+0
MBB 606	RNA Biology#	1+0
MBB 607	Plant Hormones and Signaling#	2+0
MBB 608	Computational and Statistical tools in Biotechnology#	2+1
	Any other appropriate 500 series courses	
	Minor (6 credits) from anyof the following disciplines	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Plant Physiology	
	Plant Pathology	
	Entomology	
	Bioinformatics	
	Plant Genetic Resources	
	Any other related discipline	
	Supporting (5 credits) from the following disciplines	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Bioinformatics	
	Computer Applications	
	Statistics	
	Common Courses	-
MBB	Seminar I	0+1
MBB	Seminar II	0+1
MBB 600	Research	0+75
	Total	**100**

*Core Courses; # New Courses

Course Contents
Ph.D. in Molecular Biology and Biotechnology

I. Course Title : Plant Molecular Biology

II. Course Code : MBB 601

III. Credit Hours : 3+0

IV. Aim of the course

- To provide in depth knowledge of recent developments of plant molecular biology and applications
- To discuss case studies and success stories in agriculture and industry

V. Theory

Unit I (10 Lectures)

Model Systems in Plant Biology (Arabidopsis, Rice, etc.) Forward and Reverse Genetic Approaches. Organization expression and interaction of nuclear, Mitochondrial and Chloroplast Genomes. Cytoplasmic male sterility.

Unit II (12 Lectures)

Transcriptional and Post-transcriptional Regulation of Gene Expression, Isolation of promoters and other regulatory elements, RNA interference, Transcriptional Gene Silencing, Transcript and Protein Analysis.

Unit III (12 Lectures)

Plant Developmental Processes, ABC Model of Floral Development, Role of hormones (Ethylene, Cytokinin, Auxin and ABA, SA and JA) in plant development. Regulation of Flowering, Plant photoreceptors and light signal transduction, vernalization, Circadian Rhythms.

Unit IV (14 Lectures)

Abiotic Stress Responses: Salt, Cold, Heat and Drought.Biotic Stress Responses. Molecular Biology of Plant-pathogen Interactions, Molecular Biology of *Rhizobium* and *Agrobacterium*- Plant interaction. Role of programmed Cell Death in Development and Defense.

VI. Suggested Reading

- Buchanan, B.B., Gruissem, W. and Jones R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley and Blackwell Publications.
- Slater, A., Scott, N.W., and Fowler, M.R. 2003. *The Genetic Manipulation of Plants. Plant Biotechnology Oxford, England: Oxford University Press*.
- Walker, J.M., Rapley, R. 2008. *Plant Biotechnology and Genetics: Principles, Techniques and Applications*.

I. Course Title : Plant Genome Engineering

II. Course Code : MBB 602

III. Credit Hours : 3+0

IV. Aim of the course

To discuss the specialized topics and advances in field of genetic engineering and application of molecular tools in breeding of specific crops.

V. Theory

Unit I (14 Lectures)

Conventional versus non-conventional methods for crop improvement; Present status and recent developments on available molecular marker, transformation and genomic tools for crop improvement.Genetic engineering for resistance against abiotic (drought, salinity, flooding, temperature, etc) and biotic (insect pests, fungal, viral and bacterial diseases, weeds, etc) stresses; Genetic Engineering for increasing crop productivity by manipulation of photosynthesis, nitrogen fixation and nutrient uptake efficiency; Genetic engineering for quality improvement (protein, essential amino acids, vitamins, mineral nutrients, etc.); edible vaccines, etc.

Unit II (12 Lectures)

Recent developments in plant transformation strategies; Role of antisense and RNAi-based gene silencing in crop improvement; Regulated and tissue-specific expression of transgenes for crop improvement;

Unit III (12 Lectures)

Gene stacking; Pathway engineering; Marker-free transgenic development strategies; Genome editing: principles and methods, Development of genome edited plants; High throughput phenotyping of transgenic plants.

Unit IV (10 Lectures)

Field studies with transgenic crops; Environmental issues associated with transgenic crops; Food and feed safety issues associated with transgenic crops; Risk assessment of transgenic food crops.

VI. Suggested Reading

- Christou P and Klee H. 2004. *Handbook of Plant Biotechnology*. John Wiley & Sons.
- Stewart Jr, C.N. 2016. *Plant Biotechnology and Genetics: Principles, Techniques, and Applications*. John Wiley & Sons.
- Kirakosyan A and Kaufman PB. 2009. *Recent Advances in Plant Biotechnology* p. 409. Dordrecht: Springer.

I. Course Code : MBB603

II. Course Title : Plant Omics and Molecular Breeding

III. Credit Hours : 3+0

IV. Aim of the course

To discuss the specialized topics and advances in field of genomics and genomics assisted molecular breeding.

V. Theory

Unit I (12 Lectures)

Complex traits and genetic architecture, Mapping genes and QTLs, statistical concepts in QTL mapping, high-throughput genotyping using automated platforms, genetic and physical mapping of genomes, study of population structure and kinship, association genetic analysis of QTL, case studies on QTL mapping using different approaches, map-based of cloning genes and QTLs – case studies.

Unit II (12 Lectures)

Marker Assisted Breeding (MAB): Principles and methods, marker assisted foreground and background selection, marker assisted recurrent selection, whole genome selection, case studies in MAS, requirement for successful marker assisted breeding, cost of MAB.

Unit III (12 Lectures)

Concepts and methods of next generation sequencing (NGS), assembly and annotation of NGS data, genome resequencing, DNA sequence comparison, annotation and gene prediction. Genome-wide insertion mutagenesis and its use in functional genomics, transcriptome profiling using microarrays and deep sequencing, study of methylome and its significance, proteome analysis using mass spectrometry, crystallography and NMR, analysis of proteome data, study of protein- protein interactions.

Unit IV (12 Lectures)

Study of themetabolome, use of 1D/2D NMR and MS in metabolome analysis, multivariate analysis and identification of metabolite as biomarkers, study of ionome using inductively coupled plasma – mass spectroscopy (ICP-MS), correlating the data from genome, transcriptome, proteome, metabolome and ionome with phenome.

VI. Suggested Reading

- Speicher, D.W. (Ed.). 2004. *Proteome analysis: interpreting the genome*. Elsevier.
- Tomita, M. and Nishioka, T. (Eds.). 2006. *Metabolomics: the frontier of systems biology*. Springer Science and Business Media
- Horst, L. and Wenzel, G. (Eds.). 2007. *Molecular marker systems in plant breeding and crop improvement* (Vol. 55). Springer Science and Business Media.
- Stewart C.N. 2008. *Plant Biotechnology and Genetics: Principles, Techniques and Applications*.
- Singh, B.D. and Singh, A.K. 2015. *Marker-Assisted Plant Breeding: Principles and Practices* Springer (India) Pvt. Ltd.

I. Course Title : Commercial Plant Tissue Culture

II. Course Code : MBB 604

III. Credit Hours : 2+0

IV. Aim of the course

- To provide awareness into development of commercial scale plant tissue culture units.
- To provide an insight into the commercial applications of plant tissue culture in agriculture, medicine and industry.
- To educate about biosafety, regulatory as well as entrepreneurship opportunities.

V. Theory

Unit I (8 Lectures)

Micro-propagation of commercially important plant species; plant multiplication, hardening, and transplantation; genetic fidelity; scaling up and cost reduction; bioreactors; synthetic seeds; management and marketing.

Unit II (8 Lectures)

Production of useful compounds via, biotransformation and secondary metabolite production: suspension cultures, immobilization, examples of chemicals being produced for use in pharmacy, medicine and industry.

Unit III (9 Lectures)

Value-addition by transformation; development, production and release of transgenic plants; patent, bio-safety, regulatory, environmental and ethical issues; management and commercialization.

Unit IV (7 Lectures)

Project planning and preparation, economics (entrepreneurship, cost profit ratio), government policies (incubators, different facilitation projects, loan opportunities). Some case studies on success stories on commercial applications of plant tissue culture. Visits to some tissue culture based commercial units/industries.

VI. Suggested Reading

- Honda, H., Liu, C., Kobayashi, T. 2001. *Large-Scale Plant Micropropagation*. In: Zhong J.J. *et al*. (eds) *Plant Cells. Advances in Biochemical Engineering / Biotechnology*, vol 72. Springer, Berlin, Heidelberg.
- Bhojwani SS and Razdan MK. 1986. *Plant tissue culture: theory and practice* (Vol. 5). Elsevier.

I. Course Title : Plant Microbe Interaction

II. Course Code : MBB 605

III. Credit Hours : 2+0

IV. Aim of the course

To discuss the specialized topics and advances in field of plantmicrobe interaction for understanding their potential in enhancing crop growth and development.

V. Theory

Unit I (8 Lectures)

Microbial communities in the soil and atmosphere, Community dynamics and population interactions with particular reference to plant–microbe and microbe-microbe interactions leading to symbiotic, associative, endophytic and pathogenic interactions, effects of microorganisms on plants, effects of plants on microorganisms. Recognition processes and signal exchange, Molecular aspects of Plant Growth Promoting Rhizobacteria (PGPR), Symbiotic diazotrophs: Rhizobia and association with legumes. Mycorrhizal associations: Ectomycorrhizae, Endomycorrhizae with particular emphasis to AM fungi, Ectendomycorrhizae. Biocontrol agents and their action, endophytes associations

Unit II (8 Lectures)

Enzymes, toxins, pili, siderophores, secretion systems of microbes and plants determining soil health, nutrient availability and uptake defense responses in plants: pamp-triggered immunity,effector-triggered susceptibility,qualitative resistance, r genes, structure and function, effector-triggered immunity, regulation of plant cell death, plant hormones in immunity, Plant parasite interactions and its molecular basis and impact on plant functions including photosynthesis, respiration, nitrogen metabolism and translocation

Unit III (8 Lectures)

Quorum sensing in bacteria, understanding microbiome,phytobiomes,dynamics, Applied and ecological aspects of symbioses and pathogen defense, techniques to study plant microbe interaction including microbe tagging, metagenomics and use of organismal databases to identify genes involved in interactions. Industrial application of agriculturally important microbes.

Unit III (8 Lectures)

Resistance mechanisms against attack by plant pathogens, gene-for-gene interactions; induced resistance; non-host resistance. Systemic Acquired Resistance (SAR) and Induced Systemic Resistance (ISR), Plant and microbial gene expression and signal exchange, specific regulators for different interactions including transgenic plants. Recognition mechanism and signal transduction during plant - pathogen interaction

VI. Suggested Reading

- Rangaswamy, G. Bhagyaraj. 1993. *Agricultural Microbiology*, Prentice Hall India.
- Stacey, G., and Keen, N.T. (Eds.). 1996. *Plant-microbe interactions*. Springer Science & Business Media.
- Dickinson M. 2005. *Molecular Plant Pathology*. Bios Scientific Press, Taylor and Francis group.
- Kosuge T and Nester EW. 1989. *Plant-Microbe Interactions: Molecular and Genetic Perspectives.*Vols I-IV. McGraw Hill.
- González MBR and Gonzalez-López J. (Eds.). 2013. *Beneficial plant-microbial interactions: ecology and applications*. CRC press.

I. Course Title : RNA Biology

II. Course Code : MBB 606

III. Credit Hours : 1+0

IV. Aim of the course

To discuss the specialized topics and advances in the field of Plant RNAs, their structure and role in cellular regulation and scope for crop improvement.

V. Theory

Unit I (4 Lectures)

RNA structure, functional evolution: RNA structure, types of RNA and function; Genome evolution- RNA as genetic material to regulatory molecule, Non-Coding RNAs, structure, function and regulation

Unit II (4 Lectures)

RNA synthesis, processing and regulation: transcription and its regulation in prokaryotes and eukaryotes; RNA splicing and editing; Translation and its regulation in prokaryotes and eukaryotes

Unit III (4 Lectures)

Genome regulation: Prokaryotic- attenuation, ribozymes, aptamers, riboswitches, CRISPER-Cas; eukaryotic-Exon skipping, nonsense-mediated decay, RNAi, Long non-coding RNA.

Unit IV (4 Lectures)

Epigenetic regulation. RNA-based gene silencing technologies and their applications for crop improvement

VI. Suggested Reading

- Elliott, D., and Ladomery, M. 2017. *Molecular biology of RNA*. Oxford University Press.
- Rao, M.R.S. (Ed.) 2017. *Long Non-Coding RNA Biology*, Springer,
- Donald, C.R., Hannon, G., Ares, M. and Nilsen, T.W. 2011. *RNA: A Laboratory Manual,* CSHL Press.
- Maas, S. (Ed.). 2013. *RNA Editing: Current Research and Future Trends*. Horizon Scientific Press.

I. Course Title : Plant Hormones and Signaling

II. Course Code : MBB 607

III. Credit Hours : 2+0

IV. Aim of the course

To provide in-depth knowledge of plant hormone and their role in plant growth and development.

V. Theory

Unit I (12 Lectures)

Hormone Biosynthesis, Metabolism and its Regulation: Auxin biosynthesis and metabolism, Gibberellin biosynthesis and Inactivation, Cytokinin biosynthesis and metabolism, Ethylene biosynthesis, Abscisic acid biosynthesis and metabolism, Brassinosteroid biosynthesis and metabolism. Salicylic acid and jasmonate biosynthesis and metabolism.

Unit II (12 Lectures)

Functioning of hormones in plant growth and development: Transport of Auxins, Induction of vascular tissues by Auxin, Hormones and the regulation of water balance, seed development and germination, Hormonal control of day length and senescence.

Unit III (12 Lectures)

Action of Hormones: Hormones in defense against insects and disease; Role of jasmonates, salicylic acids and peptide hormones for defense, growth, development and reproduction; Methods of plant hormone analysis. NPR 1 dependent Salicylic acid signaling, PAMP and effector triggered immunity, systemic acquired resistance and SA signaling.

Unit IV (12 Lectures)

Hormone Signal Transduction: Auxin metabolism, transport and signal transduction, Cytokinin types, synthesis, metabolism, transport and signal transduction, Gibberellin biosynthesis, transport, signal transduction in stem elongation & Leaf Growth, Ethylene metabolism, perception and signaling in seedling growth and development, Ethylene signal transduction in fruits and flowers, Abscisic acid metabolism, transport and signal transduction in nuclear gene expression and stomatal responses. Brassinosteroid biosynthesis, catabolism and signal transduction. Strigalactone biosynthesis, transport and signaling in plant parasitism and symbiosis. Methods of Plant Hormone Analysis**:** Quantitative analysis of plant hormones based on LC/MS.

VI. Suggested Reading

- Davies Jr. F. *et al*. 2017. Hart Mann and KRster's. *Plant Propagation: Principles and Practices*. Pearson.

I. Course Title : Computational and Statistical tools in Biotechnology

II. Course Code : MBB 608

III. Credit Hours : 2+1

IV. Aim of the course

To provide information on basic principles of computational biology and statistical tools used for data analysis

V. Theory

Unit I (8 Lectures)

Basic molecular biology; introduction to the basic principles of structure/function analysis of biological molecules; genome analysis; different types and classification of genome databases (e.g. HTGS, DNA, Protein, EST, STS, SNPs, Unigenes, etc.)

Unit II (8 Lectures)

Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing; Resampling techniques – Bootstrapping and Jack- knifing; Markov Models. Hidden Markov Models, Bayesian estimation and Gibbs sampling

Unit III (8 Lectures)

DNA sequence retrieval system, various DNA and protein sequence file formats, Basic concepts of similarity searching and sequence alignments, pair wise and multiple sequence alignments, DNA sequence analysis, different gene prediction models and gene annotation tools,

Unit IV (8 Lectures)

Protein sequence analysis and structure prediction, comparative genome analysis, phylogenetic analysis, gene expression analysis tools, programming languages and their applications in bioinformatics

VI. Practical (16)

- Different Types of Databases and Database Search and Retrieval,
- DNA and Protein Sequence Analysis,
- Similarity Searching and Multiple Alignments,
- Gene Annotation,
- Phylogenetic Analysis,
- Sequence Analysis,
- Protein Structure Prediction,

- Analysis of Microarray Data,
- Programming Languages in Bioinformatics.

VII. Suggested Reading

- Xiong J. 2012. *Essential Bioinformatics*, Cambridge University Press.
- Andreas, D.B., and Ouellette B.F.F., (Eds) 2004. *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* 3rd Edition, Wiley Interscience.
- Mount D. 2004. *Bioinformatics: Sequence and Genome Analysis*, 2nd Edition. By, CSHL Press.
- Augen J. 2004. *Bioinformatics in the Post-Genomic Era: Genome, Transcriptome, Proteome, and Information-Based Medicine*.
- Galperin M.Y. and Koonin E.V. (Eds) 2003. *Frontiers in Computational Genomics*.

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 2

Statistical Sciences

- Agricultural Statistics
- Computer Application

Contents

Acknowledgements

On behalf of the Broad Subject Matter Area (BSMA) Committee on Statistical Sciences and on our own personal behalf we wish to place on record our deepest sense of gratitude to Dr Arvind Kumar, Chairman, National Core Group and Vice Chancellor, RLBCAU, Jhansi for entrusting us with the responsibility to undertake this challenging but noble cause of revising the course curricula of all the disciplines in Statistical Sciences. This was a herculean task but the leadership of Dr Arvind Kumar, his fresh and fragrant ideas, and his knowledge and wisdom made the job easy for the committee. We would also like to articulate our feelings of indebtedness towards Dr G. Venkateshwarlu, ADG (EQR), Education Division, ICAR in particular, and for the Education Division, ICAR, in general, for providing necessary guidance from time to time and for also extending fullest support in successfully completing this exercise.

We gratefully acknowledge the full support received from Dr SD Sharma, Former Chairman, BSMA Committee (Statistical Sciences) New Delhi, during course of preparation of this report. The logistic support provided by Director and his dedicated team at ICAR-IASRI for holding the meetings of the BSMA committee and the workshop is duly acknowledged.

We have no word to express our most sincere and heartfelt gratefulness to Dr B.V.S. Sisodia, Dr S.P. Singh, Dr S.D. Samantray, and Dr A. Dhandapani members of the BSMA Committee (Statistical Sciences), whose unflinching efforts have culminated in the preparation of this report. The help received from Dr Sukanta Dash, Co-opted members of the BSMA Committee is praise worthy and we would like to express our highest appreciation of his efforts in this formidable work. The help received from Dr H.K. Jain, Head, Department of Agricultural Statistics and Computer application, Rajasthan Agriculture College, and his team members in organizing the meeting at Rajasthan Agriculture University, is held in high esteem. We would also like to express our sincere thanks to all the faculty of the meeting whose valuable suggestions have helped in shaping the course curricula.

The whole exercise started with a rough draft of course curricula prepared by the previous BSMA Committee during 2008 for which the BSMA Committee would like to convey its thankfulness to the entire members of the committee. Their help is also duly acknowledged. Another very important base material for revising the course curricula was the syllabi of the PG Courses of IARI, provided by ICAR-IASRI. The draft on the syllabi was also prepared by various members of the Committee. We very sincerely appreciate the help received from one and all which helped lay the foundation of the success of this phenomenal task.

Lastly, but most importantly, we would articulate our feelings for one and alland would like to reiterate the fact that it has been indeed a great pleasure working with everyone in the committee as well as outside the committee.

L.M. Bhar
Anil Kumar

Preamble

The origin of the discipline of Agricultural Statistics can be traced back to 1930 when the then Imperial Council of Agricultural Research decided setting up a Statistical Section to assist the State Departments of Agriculture and Animal Husbandry in planning their experiments and analysis of data. The activities of this section increased rapidly and acquired International recognition as a centre for research and training in the field of Agricultural Statistics. Training programmes were started in this discipline in 1945. This activity resulted in the conversion of this section to a full-fledged Institute named as Institute of Agricultural Research Statistics (IARS) where subsequently the M.Sc. and Ph.D. degree courses in Agricultural Statistics were started in 1964 in collaboration with Indian Agricultural Research Institute (IARI). With the strengthening of NARS through more SAUs and ICAR Institutes, the demand for trained and qualified manpower in Agricultural Statistics increased rapidly which resulted in starting of M.Sc. and Ph. D. degree courses in Agricultural Statistics in many other State Agricultural Universities (SAUs) and Deemed-to-be Universities (DUs). Throughout the growth of this discipline, the main emphasis was to develop trained manpower in the country in the field of Agricultural Statistics and later on in the field of Computer Application so as to meet the challenges of agricultural research in the newer emerging areas. These disciplines have now become an integrated component of agricultural research and help in making agricultural research globally acceptable.

Use of computers in agricultural research began more than three decades ago. Initially the electronic data processing requirements of agricultural research workers and students in the NARS were catered by ICAR-Indian Agricultural Statistics Research Institute (ICAR-IASRI). Late sixties and seventies saw statisticians - programmers at IASRI shouldering the onerous responsibility of training agricultural research workers in the use of computers. Around the same time a course on Computer Programming was introduced and offered in the curriculum of M.Sc. and Ph.D. students of PG School of IARI and subsequently at many other SAUs. Seventies witnessed an increase in the computing facilities in NARS; there was a great demand for qualified and trained manpower to manage these facilities. During mid-eighties, M.Sc. Course in Computer Application in Agriculture was introduced in the PG programme of IARI. During this time the computing environment started witnessing changes and Mainframe computers were getting replaced by PCs. Concepts like LAN, WAN, Information Technology (IT), Databases, Information Systems, etc., all became bywords among agricultural research workers. PG Programme in Computer Science/Application was also introduced in other SAUs. Computer Application became an important discipline in agricultural research and as such this discipline was introduced in the Agricultural Research Service of the ICAR in 1985. In the present day world, the role of Information Technology has become very important. Together with the discipline of Statistics, it does wonders in agricultural research. The newer areas of research like genomics, geo-informatics, market intelligence, quality management depend very heavily on Statistics and Information Technology. For outreaching the research in the labs to the farmers, information technology plays a vital role. Advisory and consultancy, distance learning, etc. have become possible through IT only. Data warehouses and data mining are the orders of the day.

In view of the importance of Statistical Sciences, it is important that the course curricula framed to initiate the students to conduct research in these areas and to expose them to their applications to agricultural sciences.Courses Syllabi content should have modified as practical oriented and job oriented. All modifications in syllabus are must be focused to Govt. sector and Corporate sector/ Industrial Benefits. Accordingly, a national level core group was constituted to revise the syllabi of agricultural sciences so as to cater to the requirements of the present day world. A Broad Subject Matter Area (BSMA) Committee for statistical sciences was constituted to look into the revision of the course curricula of the disciplines of Agricultural Statistics and ComputerApplication.

A meeting of the BSMA committee was held on 10th August, 2018 at IASRI, New Delhi to initiate the process of course curricula revision. The need for revision of the curricula was discussed and highlighted the importance and scope of statistical sciences due to its high practical applications in basic and applied research in agriculture. It wasalso emphasized about the need to broaden the scope, explore possibilities of collaboration and cooperation in all courses and to introduce technology oriented courses in statistical sciences. It was felt that the revised curricula should include all the necessary courses required to be studied by M.Sc. and Ph.D. students so as to prepare them to initiate the students to conduct research in these areas and to expose them to their applications to agricultural sciences. It was decided to ensure that the curricula mustbe modified as practical oriented and job oriented to handle competitive exam at both National and International level. Further, the course curricula should be such that it is focused to Govt. sector and Corporate sector/ Industrial Benefits. It was also felt that the curricula should be so framed that it includes the courses on newer areas of research. The committee members were then assigned the responsibility of restructuring the course curricula.

Thereafter another meeting of the BSMA committee was held during 24-25 November, 2018 at Rajasthan Agriculture College, MPUAT, Udaipur in which the revised course curricula was discussed. The committee was enlarged by inviting some experienced faculty members so as to take advantage of their experience. Several new courses were introduced. Since there are no Master's degrees of Computer applications in any SAUs except IARI, hence, it was decided to prepare the syllabus of computer applications in a view of IARI course content. Two courses for Ph.D. prgoramme in agricultural statistics have been restructuredand renamed as per modifications such as 'Advanced Statistical Computing' modified as 'Advanced Data Analytics' and 'Statistical Modeling' modified as 'Modeling Techniques for Forecasting'. Also the course 'Advanced Statistical Methods' was partitioned to two different courses as (i) 'Advanced Statistical Methods' and (ii) Linear Models.

A major recommendation from the meeting was to introduce many new course on computer application based on emerging issues in education like (i) IT Informatics-IT in Agriculture, (ii) Internet Technologies, (iii) Introduction to Big Data, (iv) Introduction to IoT, (v) Management Information. Also several courses have been restructuredand renamed as per modifications in computer application for both M.Sc. and Ph.D. programme.

Organization of Course Contents and Credit Requirements

- The current nomenclature of M.Sc. and Ph.D. programme has been finalized as M.Sc. (Ag.) Statistics/ Computer application and Ph.D. (Agricultural Statistics/ Computer Application).
- All courses are divided into two series: 500-series courses pertain to Master's level, and 600-series to Doctoral level. A Ph.D. student must take 500-series courses if not studied during Master's programme.
- Master's programme have a minimum 70 Credit Hours (consisting of 20 from core course, 8 from minorcourse, 6 from supporting course, 5 from common course, 1 credit seminar and 30 research credit hours).
- Similarly, for Ph.D. programme,the members suggested a total of 100 credit hours (including 12 from core course, 6 from minorcourse, 5 from supporting course, 2 credit seminars and 75 credit for research work).
- Maximum of credit load of 20 credit hours and 18 credit hours per semester for M.Sc. and Ph.D. programmes respectively.
- Credit seminar for Master's level is designated by Code no. 591, and the two seminars for Doctoral level are coded as 691 and 692, respectively.
- Similarly, 599 and 699 codes have been given for Master's research and Doctoral research, respectively.

Course Contents

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not unequivocally exclude other such reference material that may be recommended according to the advancements and local requirements.
- A list of journals pertaining to the discipline is provided at the end which may be useful as study material for 600-series courses as well as research topics.
- E-Resources - for quick update on specific topics/events pertaining to the subject.
- Broad research topics provided at the end would facilitate the advisors for appropriate research directions to the Students.

Minimum Credit Requirements

		Masters' Programme	Doctoral Programme
i.	Course work		
	Major courses	20	12
	Minor courses	08	06
	Supporting courses	06	05
	Common courses	05	–
	Seminar	01	02
ii.	**Thesis Research**	30	75
	Total	70	100

Major courses: From the Discipline in which a student takes admission. Among the listed courses, the core courses compulsorily to be taken given *mark.

Minor courses: From the subjects closely related to a student's major subject.

Supporting courses: The subject not related to the major subject. It could be any subject considered relevant for student's research work (such as Statistical Methods, Design of Experiments, etc.) or necessary for building his/her overall competence.

Common Courses: The following courses(one credit each) will be offered to all students undergoing Master's degree programme.

1. Library and Information Services
2. Technical Writing and Communications Skills
3. Intellectual Property and its management in Agriculture
4. Basic Concepts in Laboratory Techniques
5. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approvalof the HoD/ BoS.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Statistical Sciences
– Agricultural Statistics

Course Title with Credit Load
M.Sc. in Agricultural Statistics

Course Code	Course Title	Credit Hours	Semester
*STAT 552	Probability Theory	2+0	I
*STAT 553	Statistical Methods	2+1	I
*STAT 562	Statistical Inference	2+1	II
*STAT 563	Design of Experiments	2+1	II
*STAT 564	Sampling Techniques	2+1	II
*STAT 565	Statistical Genetics	2+1	II
*STAT 571	Multivariate Analysis	2+1	III
*STAT 572	Regression Analysis	1+1	III
*STAT 573	Statistical Computing	1+1	III
STAT 591	Seminar	0+1	III
STAT 599	Research	0+30	II-IV
STAT 551	Mathematics-I	3+0	I
STAT 554	Actuarial Statistics	2+0	I
STAT 555	Bioinformatics	2+0	I
STAT 556	Econometrics	2+0	I
STAT 561	Mathematics-II	2+0	II
STAT 566	Statistical Quality Control	2+0	II
STAT 567	Optimization Techniques	1+1	II
STAT 574	Time Series Analysis	1+1	III
STAT 575	Demography	2+0	III
STAT 576	Statistical Methods for Life Sciences	2+0	III
STAT 577	Statistical Ecology	2+0	III
	Supporting Courses		
STAT 501	Mathematics for Applied Sciences	2+0	I
STAT 502	Statistical Methods for Applied Sciences	3+1	I
STAT 511	Experimental Designs	2+1	II
STAT 512	Basic Sampling Techniques	2+1	II
STAT 521	Applied Regression Analysis	2+1	III
STAT 522	Data Analysis Using Statistical Packages	2+1	III

*Core Courses

Course Contents
M.Sc. in Agricultural Statistics

I. Course Title : Mathematics for Applied Sciences

II. Course Code : STAT 501

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for students who do not have sufficient background of Mathematics. The students would be exposed to elementary mathematics that would prepare them to study their main courses that involve knowledge of Mathematics. The students would get an exposure to Linear Algebra, differentiation, integration and differential equations etc.

V. Theory

Unit I

Set theory-set operations, finite and infinite sets, operations of set, function.

Unit II

Vectors and vector spaces, Matrices notations and operations, laws of matrix algebra; transpose and inverse of matrix, Eigen values and Eigen vectors. Determinants - evaluation and properties of determinants, Solutions of Linear Equations.

Unit III

Variables and functions, limits and continuity of specific functions. Differentiation: theorems of differentiation, differentiation of logarithmic, trigonometric, exponential and inverse functions, Differentiation of function of a function, derivatives of higher order, partial derivatives. Application of derivatives, determination of points of inflexion, maxima and minima.

Unit IV

Integration, methods of integration, reduction formulae, definite and indefinite integral, Applications of integration in Agriculture, Differential Equations.

VI. Suggested Reading

- Hohn FE. 2013. *Elementary Matrix Algebra*, 3rd Ed., Kindle Edition
- Harville D.A. 1997. *Matrix Algebra from a Statistician's Perspective*. Springer.
- Hohn F.E. 1973. *Elementary Matrix Algebra*. Macmillan.
- Searle S.R. 1982. *Matrix Algebra Useful for Statistics*. John Wiley. Stewart J. 2007. *Calculus*. Thompson.
- Thomas G.B. Jr. and Finney R.L. 1996. *Calculus*. 9th Ed. Pearson Edu.

I. Course Title : Statistical Methods for Applied Sciences

II. Course Code : STAT 502

III. Credit Hours : 3+1

IV. Aim of the course

This course is meant for students who do not have sufficient background of Statistical

Methods. The students would be exposed to concepts of statistical methods and statistical inference that would help them in understanding the importance of statistics. It would also help them in understanding the concepts involved in data presentation, analysis and interpretation. The students would get an exposure to presentation of data, probability distributions, parameter estimation, tests of significance, regression and multivariate analytical techniques.

V. Theory

Unit I

Box-plot, Descriptive statistics, Exploratory data analysis, Theory of probability, Random variable and mathematical expectation.

Unit II

Discrete and continuous probability distributions, Binomial, Poisson, Negative Binomial, Normal distribution, Beta and Gamma distributions and their applications. Concept of sampling distribution: chi-square, t and F distributions. Tests of significance based on Normal, chi-square, t and F distributions.

Unit III

Introduction to theory of estimation and confidence-intervals, Simple and multiple correlation coefficient, partial correlation, rank correlation, Simple and multiple linear regression model, test of significance of correlation coefficient and regression coefficients, Coefficient of determination, Fitting of quadratic models.

Unit IV

Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Run test for the randomness of a sequence. Median test.

Unit V

Introduction to ANOVA: One way and Two Way, Introduction to Sampling Techniques, Introduction to Multivariate Analysis, Transformation of Data.

VI. Practical

- Exploratory data analysis, fitting of distributions ~ Binomial, Poisson, Negative Binomial, Normal.
- Large sample tests, testing of hypothesis based on exact sampling distributions ~ chi square, t and F.
- Confidence interval estimation and Correlation and regression analysis, fitting of Linear and Quadratic Model.
- Non-parametric tests. ANOVA: One way, Two Way, SRS.

VII. Suggested Reading

- Goon A.M, Gupta M.K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A.M, Gupta M.K. and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. The World Press.
- Hoel P.G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R.V and Craig T.T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Morrison D.F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Hogg RV, McKean JW, Craig AT. 2012. *Introduction to Mathematical Statistics* 7th Edition.
- Siegel S, Johan N & Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.
- Anderson TW. 2009. *An Introduction to Multivariate Statistical Analysis*, 3rd Ed . John Wiley

- http://freestatistics.altervista.org/en/learning.php.
- http://www.statsoft.com/textbook/stathome.html.

I. Course Title : Experimental Designs

II. Course Code : STAT 511

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students of agricultural and animal sciences other than Agricultural Statistics. Designing an experiment is an integrated component of research in almost all sciences. The students would be exposed to concepts of Design of Experiments so as to enable them to understand the concepts involved in planning, designing their experiments and analysis of experimental data.

V. Theory

Unit I

Need for designing of experiments, characteristics of a good design. Basic principles of designs- randomization, replication and local control.

Unit II

Uniformity trials, size and shape of plots and blocks, Analysis of variance, Completely randomized design, randomized block design and Latin square design.

Unit III

Factorial experiments, (symmetrical as well as asymmetrical). orthogonality and partitioning of degrees of freedom. Concept of confounding.

Unit IV

Split plot and strip plot designs, analysis of covariance and missing plot techniques in randomized block and Latin square designs; Transformations, Balanced Incomplete Block Design, resolvable designs and their applications, Lattice design, alpha design - concepts, randomization procedure, analysis and interpretation of results. Response surfaces. Combined analysis.

VI. Practical

- Uniformity trial data analysis, formation of plots and blocks, Fairfield Smith Law, Analysis of data obtained from CRD, RBD, LSD, Analysis of factorial experiments,
- Analysis with missing data,
- Split plot and strip plot designs.

VII. Suggested Reading

- Cochran WG and Cox GM. 1957. *Experimental Designs*. 2nd Ed. John Wiley.
- Dean AM and Voss D. 1999. *Design and Analysis of Experiments*. Springer.
- Montgomery DC. 2012. *Design and Analysis of Experiments*, 8th Ed. John Wiley.
- Federer WT. 1985. *Experimental Designs*. MacMillan.
- Fisher RA. 1953. *Design and Analysis of Experiments*. Oliver & Boyd.
- Nigam AK and Gupta VK. 1979. *Handbook on Analysis of Agricultural Experiments*. IASRI Publ.
- Pearce SC. 1983. *The Agricultural Field Experiment: A Statistical Examination of Theory and Practice*. John Wiley.
- www.drs.icar.gov.in.

I. Course Title : Basic Sampling Techniques
II. Course Code : STAT 512
III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students of agricultural and animal sciences other than Statistics. The students would be exposed to elementary sampling techniques. It would help them in understanding the concepts involved in planning and designing their surveys, presentation of survey data analysis of survey data and presentation of results. This course would be especially important to the students of social sciences.

V. Theory

Unit I

Concept of sampling, sample survey vs complete enumeration, planning of sample survey, sampling from a finite population.

Unit II

Simple random sampling with and without replacement, sampling for proportion, determination of sample size, inverse sampling, Stratified sampling.

Unit III

Cluster sampling, Multi-stage sampling, systematic sampling; Introduction to PPS sampling,

Unit IV

Use of auxiliary information at estimation, Ratio product and regression estimators. Double Sampling, sampling and non-sampling errors.

VI. Practical

- Random sampling ~ use of random number tables, concepts of unbiasedness, variance, etc.;
- Simple random sampling, determination of sample size, inverse sampling, stratified sampling, cluster sampling and systematic sampling;
- Estimation using ratio and regression estimators;
- Estimation using multistage design, double sampling.

VII. Suggested Reading

- Cochran WG. 1977. *Sampling Techniques*. John Wiley.
- Murthy MN. 1977. *Sampling Theory and Methods*. 2nd Ed. Statistical Publ. Soc., Calcutta.
- Singh D, Singh P and Kumar P. 1982. *Handbook on Sampling Methods*. IASRI Publ.
- Sukhatme PV, Sukhatme BV, Sukhatme S and Asok C. 1984. *Sampling Theory of Surveys with Applications*. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.
- Cochran WG. 2007. *Sampling Techniques*, 3rd Edition. John Wiley & Sons Publication

I. Course Title : Applied Regression Analysis
II. Course Code : STAT 521
III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students of all disciplines including agricultural and animal sciences. The students would be exposed to the concepts of correlation and regression. Emphasis will be laid on diagnostic measures such as autocorrelation, multi collinearity and heteroscedasticity. This course would prepare students to handle their data for analysis and interpretation.

V. Theory

Unit I

Introduction to correlation analysis and its measures, Correlation from grouped data, correlation, Rank correlation, Testing of population correlation coefficients; Multiple and partial correlation coefficients and their testing.

Unit II

Problem of correlated errors; Auto correlation; Heteroscedastic models, Durbin Watson Statistics; Removal of auto correlation by transformation; Analysis of collinear data; Detection and correction of multi collinearity, Regression analysis; Method of least squares for curve fitting; Testing of regression coefficients; Multiple and partial regressions.

Unit III

Diagnostic of multiple regression equation; Concept of weighted least squares; regression equation on grouped data; Various methods of selecting the best regression equation.

Unit IV

Concept of nonlinear regression and fitting of quadratic, exponential and power curves; Economic and optimal dose, Orthogonal polynomial.

VI. Practical

- Correlation coefficient, various types of correlation coefficients, partial and multiple, testing of hypotheses;
- Multiple linear regression analysis, partial regression coefficients, testing of hypotheses, residuals and their applications in outlier detection;
- Handling of correlated errors, multi collinearity;
- Fitting of quadratic, exponential and power curves, fitting oforthogonal polynomials.

VII. Suggested Reading

- Kleinbaum DG, Kupper LL, Nizam A. 2007. *Applied Regression Analysis and Other Multivariable Methods* (Duxbury Applied) 4th Ed.
- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Ezekiel M. 1963. *Methods of Correlation and Regression Analysis*. John Wiley.
- Koutsoyiannis A. 1978. *Theory of Econometrics*. MacMillan.
- Kutner MH, Nachtsheim CJ and Neter J. 2004. *Applied Linear Regression Models*. 4th Ed. With Student CD. McGraw Hill.

I. Course Title : Data Analysis Using Statistical Packages

II. Course Code : STAT 522

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for exposing the students in the usage of various statistical packages for analysis of data. It would provide the students a hands on experience in the analysis of their research data. This course is useful to all disciplines.

V. Theory

Unit I

Introduction to various statistical packages: Excel, R, SAS, SPSS. Data Preparation; Descriptive statistics; Graphical representation of data, Exploratory data analysis.

Unit II

Test for normality; Testing of hypothesis using chi-square, t and F statistics and Z-test.

Unit III

Data preparation for ANOVA and ANCOVA, Factorial Experiments, contrast analysis, multiple comparisons, Analyzing crossed and nested classified designs.

Unit IV

Analysis of mixed models; Estimation of variance components; Correlation and regression analysis, Probit, Logit and Tobit Models.

Unit V

Discriminant function; Factor analysis; Principal component analysis; Analysis of time series data, Fitting of non-linear models; Neural networks.

VI. Practical

- Use of software packages for summarization and tabulation of data, obtaining descriptive statistics, graphical representation of data;
- Testing the hypothesis for one sample t-test, two sample t-test, paired t-test, test for large samples - Chi-squares test, F test, one-way analysis of variance;
- Designs for Factorial Experiments, fixed effect models, random effect models, mixed effect models, estimation of variance components;
- Linear regression, Multiple regression, Regression plots;
- Discriminant analysis - fitting of discriminant functions, identification of important variables;
- Factor analysis. Principal component analysis - obtaining principal component.

VII. Suggested Reading

- Anderson C.W. and Loynes R.M. 1987. *The Teaching of Practical Statistics*. John Wiley.
- Atkinson A.C. 1985. *Plots Transformations and Regression*. Oxford University Press.
- Chambers J.M., Cleveland W.S., Kleiner B and Tukey P.A. 1983. *Graphical Methods for Data Analysis*. Wadsworth, Belmount, California.
- Chatfield C. 1983. *Statistics for Technology*. 3rd Ed. Chapman & Hall. Chatfield C. 1995. *Problem Solving: A Statistician's Guide*. Chapman & Hall.
- Cleveland W.S. 1985. *The Elements of Graphing Data*. Wadsworth, Belmont, California.
- Ehrenberg ASC. 1982. *A Primer in Data Reduction*. John Wiley.
- Erickson B.H. and Nosanchuk T.A. 1992. *Understanding Data*. 2nd Ed. Open University Press, Milton Keynes.
- Snell E.J. and Simpson HR. 1991. *Applied Statistics: A Handbook of GENSTAT Analyses*. Chapman and Hall.
- Sprent P. 1993. *Applied Non-parametric Statistical Methods*. 2nd Ed. Chapman & Hall.
- Tufte ER. 1983. *The Visual Display of Quantitative Information*. Graphics Press, Cheshire, Conn.
- Velleman PF and Hoaglin DC. 1981. *Application, Basics and Computing of Exploratory Data Analysis*. Duxbury Press.
- Weisberg S. 1985. *Applied Linear Regression*. John Wiley.
- Wetherill GB. 1982. *Elementary Statistical Methods*. Chapman & Hall.

- Wetherill GB.1986. *Regression Analysis with Applications*. Chapman & Hall.
- Cleveland WS. 1994. *The Elements of Graphing Data*, 2nd Ed., Chapman & Hall
- http://freestatistics.altervista.org/en/learning.php.
  http://freestatistics.altervista.org/en/stat.php.
  http://www.cas.lancs.ac.uk/glossary_v1.1/main.html.
  http://www.stat.sc.edu/~grego/courses/stat706/.
- www.drs.icar.gov.in.

I. Course Title : Mathematics-I

II. Course Code : STAT 551

III. Credit Hours : 3+0

IV. Aim of the course

This course lays the foundation of all other courses of Agricultural Statistics discipline by preparing them to understand the importance of mathematical methods in research. The students would be exposed to the basic mathematical tools of real analysis, calculus, differential equations and numerical analysis. This would prepare them to study their main courses that involve knowledge of Mathematics.

V. Theory

Unit I

Calculus: Limit and continuity, differentiation of functions, successive differentiation, partial differentiation, mean value theorems, Taylor and Maclaurin's series. Application of derivatives, L'hospital's rule.

Unit II

Real Analysis: Convergence and divergence of infinite series, use of comparison tests -D'Alembert's Ratio - test, Cauchy's nth root test, Raabe's test, Kummer's test, Gauss test. Absolute and conditional convergence. Riemann integration, concept of Lebesgue integration, power series, Fourier, Laplace and Laplace -Steiltjes' transformation, multiple integrals.Integration of rational, irrational and trigonometric functions. Application of integration.

Unit III

Differential equation: Differential equations of first order, linear differential equations of higher order with constant coefficient.

Unit IV

Numerical Analysis: Simple interpolation, Divided differences, Numerical differentiation and integration.

VI. Suggested Reading

- Bartle RG. 1976. *Elements of Real Analysis*. John Wiley. Chatterjee SK. 1970. *Mathematical Analysis*. Oxford & IBH.
- Gibson GA. 1954. *Advanced Calculus*. Macmillan.
- Henrice P. 1964. *Elements of Numerical Analysis*. John Wiley.
- Hildebrand FB. 1956. *Introduction to Numerical Analysis*. Tata McGraw Hill.
- Priestley HA. 1985. *Complex Analysis*. Clarenton Press.
- Rudin W. 1985. *Principles of Mathematical Analysis*. McGraw Hill. Sauer T. 2006. *Numerical Analysis With CD-Rom*. Addison Wesley. Scarborough JB. 1976. *Numerical Mathematical Analysis*. Oxford & IBH. Stewart J. 2007. *Calculus*.Thompson.
- Thomas GB Jr. and Finney RL. 1996. *Calculus*. 9th Ed. Pearson Edu.

I. Course Title : Probability Theory

II. Course Code : STAT 552

III. Credit Hours : 2+0

IV. Aim of the course

This is a fundamental course in Statistics. This course lays the foundation of probability theory, random variable, probability distribution, mathematical expectation, etc. which forms the basis of basic statistics. The students are also exposed to law of large numbers and central limit theorem. The students also get introduced to stochastic processes.

V. Theory

Unit I

Basic concepts of probability. Elements of measure theory: class of sets, field, sigma field, minimal sigma field, Borel sigma field in R, measure- probability measure. Axiomatic approach to probability. Properties of probability based on axiomatic definition. Addition and multiplication theorems. Conditional probability and independence of events. Bayes theorem.

Unit II

Random variables: definition of random variable, discrete and continuous, functions of random variables. Probability mass function and Probability density function, Distribution function and its properties. Notion of bivariate random variables, bivariate distribution function and its properties. Joint, marginal and conditional distributions. Independence of random variables. Transformation of random variables (two dimensional caseonly). Mathematical expectation: Mathematical expectation of functions of a random variable. Raw and central moments and their relation, covariance, skewness and kurtosis. Addition and multiplication theorems of expectation. Definition of moment generating function, cumulating generating function, probability generating function and statements of their properties.

Unit III

Conditional expectation and conditional variance. Characteristic function and its properties. Inversion and uniqueness theorems. Chebyshev, Markov, Cauchy-Schwartz, Sequence of random variables and modes of convergence (convergence in distribution in probability, almost surely, and quadratic mean) and their interrelations.

Unit IV

Laws of large numbers: WLLN, Bernoulli and Kintchin's WLLN. Kolmogorov inequality, Kolmogorov's SLLNs.Central Limit theorems: Demoviere- Laplace CLT, Lindberg – Levy CLT and simple applications.

VI. Suggested Reading

- Ash RB. 2000. *Probability and Measure Theory*. 2nd Ed. Academic Press. Billingsley P. 1986. *Probability and Measure*. 2nd Ed. John Wiley.
- Capinski M and Zastawniah. 2001. *Probability Through Problems*. Springer. Dudewicz EJ & Mishra SN. 1988. *Modern Mathematical Statistics*. John Wiley.
- Feller W. 1972. *An Introduction to Probability Theory and its Applications*. Vols. I., II. John Wiley.
- Loeve M. 1978. *Probability Theory*. 4th Ed. Springer.

- Marek C, Tomasz JZ. 2003. *Probability* Through Problems (Problem Books in Mathematics) Corrected Ed.
- Marek F. 1963. *Probability Theory and Mathematical Statistics*. John Wiley.
- Rohatgi VK & Saleh AK Md. E. 2005. *An Introduction to Probability and* Statistics. 2nd Ed. John Wiley.

I. Course Title : Statistical Methods

II. Course Code : STAT 553

III. Credit Hours : 2+1

IV. Aim of the course

This course lays the foundation of probability distributions and sampling distributions and their application which forms the basis of Statistical Inference. Together with probability theory, this course is fundamental to the discipline of Statistics. The students are also exposed to correlation and regression, and order statistics and their distributions. Categorical data analysis is also covered in this course.

V. Theory

Unit I

Descriptive statistics: probability distributions: Discrete probability distributions ~ Bernoulli, Binomial, Poisson, Negative-binomial, Geometric and Hyper Geometric, uniform, multinomial ~ Properties of these distributions and real life examples. Continuous probability distributions ~ rectangular, exponential, Cauchy, normal, gamma, beta of two kinds, Weibull, lognormal, logistic, Pareto. Properties of these distributions. Probability distributions of functions of random variables.

Unit II

Concepts of compound, truncated and mixture distributions (definitions and examples). Sampling distributions of sample mean and sample variance from Normal population, central and non–central chi-Square, t and F distributions, their properties and inter relationships.

Unit III

Concepts of random vectors, moments and their distributions. Bivariate Normal distribution - marginal and conditional distributions. Distribution of quadratic forms. Cochran theorem. Correlation, rank correlation, correlation ratio and intra-class correlation. Regression analysis, partial and multiple correlation andregression.

Unit IV

Sampling distribution of correlation coefficient, regression coefficient. Categorical data analysis, Association between attributes. Variance StabilizingTransformations.

Unit V

Order statistics, distribution of r-th order statistics, joint distribution of several order statistics and their functions, marginal distributions of order statistics.

VI. Practical

- Fitting of discrete distributions and test for goodness of fit;
- Fitting of continuous distributions and test for goodness of fit; Fitting of truncated distribution;

- Computation of simple, multiple and partial correlation coefficient, correlation ratio and intra-class correlation;
- Regression coefficients and regression equations;
- Fitting of Pearsonian curves;
- Analysis of association between attributes, categorical data and log-linear models.

VII. Suggested Reading

- Agresti, A. 2012. *Categorical Data Analysis* 3rd Ed. John Wiley.
- Arnold BC, Balakrishnan N and Nagaraja HN. 1992. *A First Course in Order Statistics*. JohnWiley.
- David HA and Nagaraja HN. 2003. *Order Statistics*. 3rd Ed. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. *Modern Mathematical Statistics*. John Wiley.
- Huber PJ. 1981. *Robust Statistics*. John Wiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. *Continuous Univariate Distributions*. JohnWiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. *Discrete Univariate Distributions*. JohnWiley.
- Marek F.1963. *Probability Theory and Mathematical Statistics*. John Wiley.
- Rao CR. 1965. *Linear Statistical Inference and its Applications*. John Wiley.
- Rohatgi VK and Saleh AK Md. E. 2005. *An Introduction to Probability and Statistics*. 2nd Ed. John Wiley.
- Gupta. S.P 2008. *Statistical Methods*. Sultan Chand & sons Educational Publisher

I. Course Title : Actuarial Statistics

II. Course Code : STAT 554

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant to expose to the students to the statistical techniques such as probability models, life tables, insurance and annuities. The students would also be exposed top practical applications of these techniques in computation of premiums that include expenses, general expenses, types of expenses and per policy expenses.

V. Theory

Unit I

Insurance and utility theory, models for individual claims and their sums, survival function, curtate future lifetime, force of mortality.

Unit II

Life table and its relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables.

Unit III

Multiple life functions, joint life and last survivor status, insurance and annuity benefits through multiple life functions evaluation for special mortality laws. Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrement, net single premiums and their numerical evaluations.

Unit IV

Distribution of aggregate claims, compound Poisson distribution and its applications.

Unit V

Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding.

Unit VI

Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance, recursions, commutation functions.

Unit VII

Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions, varying annuities, recursions, complete annuities-immediate and apportionable annuities-due.

Unit VIII

Net premiums: Continuous and discrete premiums, true monthly payment premiums, apportionable premiums, commutation functions, accumulation type benefits. Payment premiums, apportionable premiums, commutation functions, accumulation type benefits. Net premium reserves: Continuous and discrete net premium reserve, reserves on a semi-continuous basis, reserves based on true monthly premiums, reserves on an apportionable or discounted continuous basis, reserves at fractional durations, allocations of loss to policy years, recursive formulas and differential equations for reserves, commutation functions.

Unit IX

Some practical considerations: Premiums that include expenses-general expenses types of expenses, per policy expenses. Claim amount distributions, approximating the individual model, stop-loss insurance.

VI. Suggested Reading

- Atkinson ME and Dickson DCM. 2000. *An Introduction to Actuarial Studies*. Elgar Publ.
- Bedford T and Cooke R. 2001. *Probabilistic Risk Analysis*. Cambridge.
- Booth PM, Chadburn RG, Cooper DR, Haberman, S and James DE.1999. Modern *Actuarial Theory and Practice*. Chapman & Hall.
- Borowiak Dale S. 2003. *Financial and Actuarial Statistics: An Introduction*. Marcel Dekker.
- Bowers NL, Gerber HU, Hickman JC, Jones DA and Nesbitt CJ.1997. *Actuarial Mathematics*. 2nd Ed. Society of Actuaries, Ithaca, Illinois.
- Dale SB, Arnold FS. 2013. *Financial and Actuarial Statistics: An Introduction*, 2nd Ed. (Statistics: A Series of Textbooks and Monogrphs)
- Daykin CD, Pentikainen T and Pesonen M. 1994. *Practical Risk Theory for Actuaries*. Chapman & Hall.
- Klugman SA, Panjer HH, Willmotand GE and Venter GG. 1998. *Loss Models: From data to Decisions*. John Wiley.
- Medina PK and Merino S. 2003. *Mathematical Finance and Probability: A Discrete Introduction*. Basel, Birkhauser.
- Melnikov, A. 2011. *Risk Analysis in Finance and Insurance* (Chapman & Hall/Crc Financial Mathematics Series) 2nd Ed.
- Neill A. 1977. *Life Contingencies*. Butterworth-Heinemann.
- Rolski T, Schmidli H, Schmidt V and Teugels J. 1998. *Stochastic Processes for Insurance and Finance*. John Wiley.
- Rotar VI. 2006. *Actuarial Models. The Mathematics of Insurance. Chapman*& Hall/CRC.
- Spurgeon ET. 1972. *Life Contingencies*. Cambridge Univ. Press.

I. Course Title : Bioinformatics

II. Course Code : STAT 555

III. Credit Hours : 2+0

IV. Aim of the course

Bioinformatics is a new emerging area. It is an integration of Statistics, Computer applications and Biology. The trained manpower in the area of Bioinformatics is required for meeting the new challenges in teaching and research in the discipline of Agricultural Sciences. This course is meant to train the students on concepts of basic biology, statistical techniques and computational techniques for understanding bioinformatics principals.

V. Theory

Unit I

Basic Biology: Cell, genes, gene structures, gene expression and regulation, Molecular tools, nucleotides, nucleic acids, markers, proteins and enzymes, bioenergetics, single nucleotide polymorphism, expressed sequence tag. Structural and functional genomics: Organization and structure of genomes, genome mapping, assembling of physical maps, strategies and techniques for genome sequencing and analysis.

Unit II

Computing techniques: OS and Programming Languages – *Linux, perl, bioperl,python, biopython,cgi, MySQL, phpMyAdmin*; Coding for browsing biological databases on web, parsing & annotation of genomic sequences; Database designing; Computer networks – Internet, World wide web, Web browsers– EMBnet, NCBI; Databases on public domain pertaining to Nucleic acid sequences, protein sequences, SNPs, etc.; Searching sequence databases, Structural databases.

Unit III

Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing; Resampling techniques – Bootstrapping and Jack-knifing; Hidden Markov Models; Bayesian estimation and Gibbs sampling;

Unit IV

Tools for Bioinformatics: DNA Sequence Analysis – Features of DNA sequence analysis, Approaches to EST analysis; Pairwise alignment techniques: Comparing two sequences, PAM and BLOSUM, Global alignment (The Needleman and Wunsch algorithm), Local Alignment (The Smith-Waterman algorithm), Dynamic programming, Pairwise database searching; Sequence analysis– BLAST and other related tools, Multiple alignment and database search using motif models, ClustalW, Phylogeny; Databases on SNPs; EM algorithm and other methods to discover common motifs in biosequences; Gene prediction based on Neural Networks, Genetic algorithms, Computational analysis of protein sequence, structure and function; Design and Analysis of microarray/ RNAseqexperiments.

VI. Suggested Reading

- Baldi P. and Brunak S. 2001. *Bioinformatics: The Machine Learning Approach.* 2nd Ed. (Adaptive Computation and Machine Learning). MIT Press.
- Baxevanis A.D. and Francis B.F. (Eds.). 2004. *Bioinformatics: A Practical Guide to the*

Analysis of Genes and Proteins. John Wiley.
- Bergeron B.P. 2002. *Bioinformatics Computing*. Prentice Hall.
- Duda R.O, Hart P.E and Stork D.G. 1999. *Pattern Classification*. John Wiley.
- Ewens W.J and Grant G.R. 2001. *Statistical Methods in Bioinformatics: An Introduction* (*Statistics for Biology and Health*). Springer.
- Graham B. Zweig, J. Buffett, WE. 2006.*The Intelligent Investor: The Definitive Book on Value Investing*. A Book of Practical Counsel, Revised Edition
- Hunt S and Livesy F. (Eds.). 2000. *Functional Genomics: A Practical Approach* (*The Practical Approach Series, 235*). Oxford Univ. Press.
- Jones N.C. and Pevzner P.A. 2004. *An Introduction to Bioinformatics Algorithims*. MIT Press.
- Koski T and Koskinen T. 2001. *Hidden Markov Models for Bioinformatics*. Kluwer.
- Krane D.E. and Raymer M.L. 2002. *Fundamental Concepts of Bio-informatics*. Benjamin / Cummings.
- Krawetz S.A and Womble D.D. 2003. *Introduction to Bioinformatics: A Theoretical and Practical Approach*. Humana Press.
- Lesk A.M. 2002. *Introduction to Bio-informatics*. Oxford Univ. Press.
- Percus J.K. 2001. *Mathematics of Genome Analysis*. Cambridge Univ. Press.
- Sorensen D and Gianola D. 2002. *Likelihood, Bayesian and MCMC Methods in Genetics*. Springer.
- Tisdall J.D. 2001. *Mastering Perl for Bioinformatics*. O'Reilly & Associates.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. *Data Mining in Bioinformatics*. Springer.
- Wu C.H. and McLarty J.W. 2000. *Neural Networks and Genome Informatics*. Elsevier.
- Wunschiers R. 2004. *Computational Biology Unix/Linux, Data Processing and Programming*. Springer.

I. Course Title : Econometrics

II. Course Code : STAT 556

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for training the students in econometric methods and their applications in agriculture. This course would enable the students in understanding the economic phenomena through statistical tools and economics principles.

V. Theory

Unit I

Representation of Economic phenomenon, relationship among economic variables, linear and non-linear economic models, single equation general linear regression model, basic assumptions, Ordinary least squares method of estimation for simple and multiple regression models; summary statistics correlation matrix, co-efficient of multiple determination, standard errors of estimated parameters, tests of significance and confidence interval estimation. BLUE properties of Least Squares estimates. Chow test, test of improvement of fit through additional regressors. Maximum likelihood estimation.

Unit II

Heteroscedasticity, Auto-correlation, Durbin Watson test, Multi-collinearity. Stochastic regressors, Errors in variables, Use of instrumental variables in regression analysis. Dummy Variables. Distributed Lag models: Koyck's Geometric Lag scheme, Adaptive Expectation and Partial Adjustment Mode, Rational Expectation Models and test for rationality.

Unit III

Simultaneous equation model: Basic rationale, Consequences of simultaneous relations, Identification problem, Conditions of Identification, Indirect Least Squares, Two-stage least squares, K-class estimators, Limited Information and Full Information Maximum Likelihood Methods, three stage least squares, Generalized least squares, Recursive models, SURE Models. Mixed Estimation Methods, use of instrumental variables, pooling of cross-section and time series data, Principal Component Methods.

Unit IV

Problem and Construction of index numbers and their tests; fixed and chain based index numbers; Construction of cost of living index number.

Unit V

Demand analysis – Demand and Supply Curves; Determination of demand curves from market data. Engel's Law and the Engel's Curves, Income distribution and method of its estimation, Pareto's Curve, Income inequality measures.

VI. Suggested Reading

- Croxton F.E. and Cowden D.J. 1979. *Applied General Statistics*. Prentice Hall of India.
- James H.S. and Mark W.W. 2017. Introduction to Econometrics, 3rd Ed. John Wiley
- Johnston J. 1984. *Econometric Methods*. McGraw Hill.
- Judge G.C., Hill R.C., Griffiths W.E., Lutkepohl H and Lee T.C. 1988. *Introduction to the Theory and Practice of Econometrics*. 2nd Ed. John Wiley.
- Kmenta J. 1986. *Elements of Econometrics*. 2nd Ed. University of Michigan Press.
- Koop G. 2007. *Introduction to Econometrics*. John Wiley.
- Maddala G.S. 2001. *Introduction to Econometrics*. 3rd Ed. John Wiley.
- Pindyck R.S. and Rubinfeld D.L. 1998. *Econometric Models and Economic Forecasts*. 4th Ed. McGraw Hill.
- Verbeek M. 2008. *A Guide to Modern Econometrics*. 3rd Ed. John Wiley.

I. Course Title : Mathematics-II

II. Course Code : STAT 561

III. Credit Hours : 2+0

IV. Aim of the course

This is another course that supports all other courses in Agricultural Statistics. The students would be exposed to the advances in Linear Algebra and Matrix theory. This would prepare them to study their main courses that involve knowledge of Linear Algebra and Matrix Algebra.

V. Theory

Unit I

Linear Algebra: Group, ring, field and vector spaces, Sub-spaces, basis, Gram Schmidt's orthogonalization, Galois field - Fermat's theorem and primitive elements. Linear transformations. Graph theory: Concepts and applications.

Unit II

Matrix Algebra: Basic terminology, linear independence and dependence of vectors.

Row and column spaces, Echelon form. Determinants, Trace of matrices rank and inverse of matrices. Special matrices – idempotent, symmetric, orthogonal. Eigen values and eigen vectors, Spectral decomposition of matrices.

Unit III

Unitary, Similar, Hadamard, Circulant, Helmert's matrices. Kronecker and Hadamard product of matrices, Kronecker sum of matrices. Sub-matrices and partitioned matrices, Permutation matrices, full rank factorization, Grammian root of a symmetric matrix. Solutions of linear equations, Equations having many solutions.

Unit IV

Generalized inverses, Moore-Penrose inverse, Applications of g-inverse. Inverse and Generalized inverse of partitioned matrices, Differentiation and integration of vectors and matrices, Quadratic forms.

VI. Suggested Reading

- Aschbacher M. 2000. *Finite Group Theory*. Cambridge University Press.
- Deo N. 1984. *Graph Theory with Application to Engineering and Computer Science*. Prentice Hall of India.
- Gentle JE. 2007. *Matrix Algebra: Theory, Computations and Applications in Statistics*. Springer.
- Graybill FE.1961. *Introduction to Matrices with Applications in Statistics*. Wadsworth Publ.
- Hadley G. 1969. *Linear Algebra*. Addison Wesley.
- Harville DA. 1997. *Matrix Algebra from a Statistician's Perspective*. Springer.
- Rao CR. 1965. *Linear Statistical Inference and its Applications*. 2nd Ed. John Wiley.
- Robinson DJS. 1991. *A Course in Linear Algebra with Applications*. World Scientific.
- Searle SR. 2006. *Matrix Algebra Useful for Statistics* John Wiley, 2nd Ed.
- Seber GAF. 2008. *A Matrix Handbook for Statisticians*. John Wiley.

I. Course Title : Statistical Inference

II. Course Code : STAT 562

III. Credit Hours : 2+1

IV. Aim of the course

This course lays the foundation of Statistical Inference. The students would be taught the problems related to point and confidence interval estimation and testing of hypothesis. They would also be given the concepts of nonparametric and sequential test procedures and elements of decision theory.

V. Theory

Unit I

Concepts of point estimation: unbiasedness, consistency, efficiency and sufficiency. Statement of Neyman's Factorization theorem with applications. MVUE, Rao-Blackwell theorem, completeness, Lehmann- Scheffe theorem. Fisher information, Cramer-Rao lower bound and its applications.

Unit II

Moments, minimum chi-square, least square and maximum likelihood methods of estimation and theirproperties.Interval estimation-Confidence level, shortest length CI. CI for the parameters of Normal, Exponential, Binomial and Poisson distributions.

Unit III

Fundamentals of hypothesis testing-statistical hypothesis, statistical test, critical region, types of errors, test function, randomized and non- randomized tests, level of significance, power function, most powerful tests: Neyman-Pearson fundamental lemma, MLR families and UMP tests for one parameter exponential families. Concepts of consistency, unbiasedness and invariance of tests. Likelihood Ratio tests, asymptotic properties of LR tests with applications (including homogeneity of means and variances).Relation between confidence interval estimation and testing of hypothesis.

Unit IV

Sequential Probability ratio test, Properties of SPRT.Termination property of SPRT, SPRT for Binomial, Poisson, Normal and Exponential distributions. Concepts of loss, risk and decision functions, admissible and optimal decision functions, estimation and testing viewed as decision problems, conjugate families, Bayes and Minimax decision functions with applications to estimation with quadratic loss.

Unit V

Non-parametric tests: Sign test, Wilcoxon signed rank test, Runs test for randomness, Kolmogorov – Smirnov test for goodness of fit, Median test and Wilcoxon-Mann-Whitney U-test. Chi-square test for goodness of fit and test for independence of attributes. Spearman's rank correlation and Kendall's Tau tests for independence.

VI. Practical

- Methods of estimation - Maximum Likelihood, Minimum c^2 and Moments;
- Confidence Interval Estimation;
- MP and UMP tests;
- Large Sample tests;
- Non-parametric tests, Sequential Probability Ratio Test;
- Decision functions.

VII. Suggested Reading

- Box G.E.P. and Tiao G.C. 1992. *Bayesian Inference in Statistical Analysis*.John Wiley.
- Casela G and Berger R.L. 2001. *Statistical Inference*. Duxbury Thompson Learning.
- Christensen R. 1990. *Log Linear Models*. Springer.
- Conover W.J. 1980. *Practical Nonparametric Statistics*. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. *Modern Mathematical Statistics*. JohnWiley.
- Gibbons J.D. 1985. *Non Parametric Statistical Inference*. 2^{nd} Ed. Marcel Dekker.
- Kiefer J.C. 1987. *Introduction to Statistical Inference*. Springer.
- Lehmann EL. 1986. *Testing Statistical Hypotheses*. John Wiley.
- Lehmann EL. 1986. *Theory of Point Estimation*. John Wiley.
- Randles R.H and Wolfe D.S. 1979. *Introduction to the Theory of Nonparametric Statistics*. John Wiley.
- Rao C.R. 2009. *Linear Statistical Inference and Its Applications*, 3^{rd}Ed. John Wiley.
- Rohatgi V.K. and Saleh A.K. Md. E. 2005. *An Introduction to Probability and Statistics*. 2^{nd} Ed. John Wiley.
- Rohtagi V.K. 1984. *Statistical Inference*. John Wiley
- Sidney S and Castellan N.J. Jr. 1988. *Non Parametric Statistical Methods for Behavioral Sciences*. McGraw Hill.
- Wald A. 2004. *Sequential Analysis*. Dover Publ.
- Michael J.Panik. 2012. *Statistical Inference*. A John Wiley & Sons, INC, publication

I. Course Title : Design of Experiments

II. Course Code : STAT 563

III. Credit Hours : 2+1

IV. Aim of the course

Design of Experiments provides the statistical tools to get maximum information from least amount of resources. This course is meant to expose the students to the basic principles of design of experiments. The students would also be provided with mathematical background of various basic designs involving one-way and two-way elimination of heterogeneity and their characterization properties. This course would also prepare the students in deriving the expressions for analysis of experimental data.

V. Theory

Unit I

Elements of linear estimation, Gauss Markoff Theorem, relationship between BLUEs and linear zero-functions. Aitken's transformation, test of hypothesis, Analysis of Variance, Partitioning of degrees of freedom.

Unit II

Orthogonality, contrasts, mutually orthogonal contrasts, analysis of covariance; Basic principles of design of experiments, uniformity trials, size and shape of plots andblocks, Randomization procedure.

Unit III

Basic designs - completely randomized design, randomized complete block design and Latin square design; Construction of orthogonal Latin squares, mutually orthogonal Latin squares (MOLS), Youden square designs, Graeco Latin squares.

Unit IV

Balanced Incomplete Block (BIB) designs – general properties and analysis without and with recovery of intra block information, construction of BIB designs. Partially balanced incomplete block designs with two associate classes - properties, analysis and construction, Lattice designs, alpha designs, cyclic designs, augmented designs.

Unit V

Factorial experiments, confounding in symmetrical factorial experiments ($2^n$and 3^nseries), partial and total confounding, asymmetrical factorials.

Unit VI

Cross-over designs. Missing plot technique; Split plot and Strip plot design; Groups of experiments.Sampling in field experiments.

VI. Practical

- Determination of size and shape of plots and blocks from uniformity trials data;
- Analysis of data generated from completely randomized design, randomized complete block design;
- Latin square design, Youden square design; Analysis of data generated from a BIB design, lattice design, PBIB designs;
- 2^n, 3^n factorial experiments without and with confounding;
- Split and strip plot designs, repeated measurement design;
- Missing plot techniques,

- Analysis of covariance;
- Analysis of Groups of experiments,
- Analysis of clinical trial experiments.

VII. Suggested Reading

- Chakrabarti M.C. 1962. *Mathematics of Design and Analysis of Experiments*. Asia Publ.House.
- Cochran W.G. and Cox D.R. 1957. *Experimental Designs*. 2nd Ed. John Wiley.
- Dean A.M. and Voss D. 1999. *Design and Analysis of Experiments*. Springer.
- Dey A and Mukerjee R. 1999. *Fractional Factorial Plans*. John Wiley.
- Dey A 1986. *Theory of Block Designs*. Wiley Eastern. Hall M Jr. 1986. *Combinatorial Theory*. John Wiley.
- John J.A. and Quenouille M.H. 1977. *Experiments: Design and Analysis*. Charles & Griffin.
- Kempthorne, O. 1976. Design and Analysis of Experiments. John Wiley. Khuri AI & Cornell JA. 1996. *Response Surface Designs and Analysis*. 2nd Ed. Marcel Dekker.
- Kshirsagar A.M. 1983. *A Course in Linear Models*. Marcel Dekker.
- Montgomery D.C. 2013. *Design and Analysis of Experiments*. John Wiley & Sons
- Raghavarao D. 1971. *Construction and Combinatorial Problems in Design of Experiments*. John Wiley.
- Searle S.R. 2006. *Linear Models*. John Wiley.
- Street A.P. and Street D.J. 1987. *Combinatorics of Experimental Designs*. Oxford Science Publ.
- Design Resources Server. *Indian Agricultural Statistics Research Institute (ICAR), New Delhi-110 012, India*. Hyperlink "http: //www.iasri.res.in/design" www.drs.icar.gov.in.

I. Course Title : Sampling Techniques

II. Course Code : STAT 564

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant to expose the students to the techniques of drawing representative samples from various populations and then preparing them on the mathematical formulations of estimating the population parameters based on the sample data. The students would also be exposed to the real life applications of sampling techniques and estimation of parameters.

V. Theory

Unit I

Sample survey vs complete enumeration, probability sampling, sample space, sampling design, sampling strategy; Determination of sample size; Confidence-interval; Simple random sampling, Estimation of population proportion, Stratified random sampling, Proportional allocation and optimal allocation, Inverse sampling.

Unit II

Ratio, Product and regression methods of estimation, Cluster sampling, Systematic sampling, Multistage sampling with equal probability, Separate and combined ratio estimator, Double sampling, Successive sampling –two occasions. Unbiased ratio type estimators

Unit III

Non-sampling errors – sources and classification, Non-response in surveys, Randomized response techniques, Response errors/ Measurement error – interpenetrating sub-sampling.

Unit IV

PPS Sampling with and without replacement, Cumulative method and Lahiri's method of selection, Horvitz-Thompson estimator, Ordered and unordered estimators, Sampling strategies due to Midzuno-Sen and Rao-Hartley-Cochran. Inclusion probability proportional to size sampling.

VI. Practical

- Determination of sample size and selection of sample;
- Simple random sampling, Inverse sampling, Stratified random sampling, Cluster sampling, systematic sampling;
- Ratio and regression methods of estimation;
- Double sampling, multi-stage sampling, Imputation methods;
- Randomized response techniques;
- Sampling with varying probabilities.

VII. Suggested Reading

- Cassel C.M., Sarndal C.E. and Wretman J.H. 1977. *Foundations of Inference in Survey Sampling*. John Wiley.
- Chaudhari A and Stenger H. 2005. *Survey Sampling Theory and Methods*. 2nd Ed. Chapman & Hall.
- Chaudhari A and Voss J.W.E. 1988. *Unified Theory and Strategies of Survey Sampling*. North Holland.
- Cochran W.G. 1977. *Sampling Techniques*. John Wiley.
- Hedayat A.S. and Sinha B.K. 1991. *Design and Inference in Finite Population Sampling*. John Wiley.
- Kish L. 1965. *Survey Sampling*. John Wiley.
- Mukhopadhyay, P. 2008.
- *Theory and Methods of Survey Sampling*, John Wiley & Sons
- Murthy M.N. 1977. *Sampling Theory and Methods*. 2nd Ed. Statistical Publ. Society, Calcutta.
- Sukhatme P.V., Sukhatme B.V., Sukhatme S and Asok C. 1984. *Sampling Theory of Surveys with Applications*. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.
- Thompson SK. 2000. *Sampling*. John Wiley.
- Kochran WG. 2007. *Sampling Techniques*. A John Wiley & Sons *Publication*

I. Course Title : Statistical Genetics

II. Course Code : STAT 565

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant to prepare the students in applications of statistics in quantitative genetics and breeding. The students would be exposed to the physical basis of inheritance, detection and estimation of linkage, estimation of genetic parameters and development of selection indices.

V. Theory

Unit I

Physical basis of inheritance. Analysis of segregation, detection and estimation of linkage for qualitative characters. Amount of information about linkage, combined estimation, disturbed segregation.

Unit II

Gene and genotypic frequencies, Random mating and Hardy -Weinberg law, Application and extension of the equilibrium law, Fisher's fundamental theorem of natural selection. Disequilibrium due to linkage for two pairs of genes, sex-linked genes, Theory of path coefficients.

Unit III

Concepts of inbreeding, Regular system of inbreeding. Forces affecting gene frequency - selection, mutation and migration, equilibrium between forces in large populations, Random genetic drift, Effect of finite populationsize.

Unit IV

Polygenic system for quantitative characters, concepts of breeding value and dominance deviation. Genetic variance and its partitioning, Effect of inbreeding on quantitative characters, Multipleallelism in continuous variation, Sex-linked genes, Maternal effects - estimation of their contribution.

Unit V

Correlations between relatives, Heritability, Repeatability and Genetic correlation. Response due to selection, Selection index and its applications in plants and animals' improvement programmes, Correlated response to selection.
Unit VI
Restricted selection index. Variance component approach and linear regression approach for the analysis of GE interactions. Measurement of stability and adaptability for genotypes. Concepts of general and specific combining ability. Diallel and partial diallel crosses - construction and analysis.

VI. Practical

- Test for the single factor segregation ratios, homogeneity of the families with regard to single factor segregation;
- Detection and estimation of linkage parameter by different procedures;
- Estimation of genotypic and gene frequency from a given data.
- Hardy-Weinberg law;
- Estimation of changes in gene frequency due to systematic forces, inbreeding coefficient, genetic components of variation, heritability and repeatability coefficient, genetic correlation coefficient;
- Examination of effect of linkage, epistasis and inbreeding on mean and variance of metric traits;
- Mating designs;
- Construction of selection index including phenotypic index, restricted selection index. Correlated response to selection.

VII. Suggested Reading

- Agarwal BL and Agarwal SP. 2007. *Statistical Analysis of Quantitative Genetics*. New Age International Publisher.
- Bailey NTJ. 1961. *The Mathematical Theory of Genetic Linkage*.Clarendon Press.
- Balding DJ, Bishop M and Cannings C. 2001. *Hand Book of Statistical Genetics*. John Wiley.
- Crow JF and Kimura M. 1970. *An Introduction of Population Genetics Theory*. Harper and Row.
- Dahlberg G. 1948. *Mathematical Methods for Population Genetics*. Inter Science Publ.
- East EM and Jones DF. 1919. *Inbreeding and Outbreeding*.
- Lippincott JB & Co. Ewens WJ. 1979. *Mathematics of Population Genetics*. Springer.

- Falconer DS. 1985. *Introduction to Quantitative Genetics*. ELBL.
- Fisher RA. 1949. *The Theory of Inbreeding*. Oliver & Boyd.
- Fisher RA. 1950. *Statistical Methods for Research Workers*. *Oliver*& Boyd.
- Fisher RA. 1958. *The Genetical Theory of Natural Selection*. *Dover* Publ.
- Kempthorne O. 1957. *An Introduction to Genetic Statistics*. The Iowa State Univ. Press.
- Lerner IM. 1950. *Population Genetics and Animal Improvement*.Cambridge Univ. Press.
- Lerner IM. 1954. *Genetic Homeostasis*. Oliver & Boyd.
- Lerner IM. 1958. *The Genetic Theory of Selection*. John Wiley.
- Li CC. 1982. *Population Genetics*. The University of Chicago Press.
- K & Jinks JL. 1977. *Introduction to Biometrical Genetics*.Chapman & Hall.
- Mather K and Jinks JL. 1982. *Biometrical Genetics*. Chapman & Hall.
- Mather K. 1949. *Biometrical Genetics*. Methuen.
- Mather K. 1951. *The Measurement of Linkage in Heredity*.
- Methuen. N. P. 1990. *Statistical Genetics*. Wiley Eastern.

I. Course Title : Statistical Quality Control

II. Course Code : STAT 566

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for exposing the students to the concepts of Statistical Quality Control and their applications in agribusiness and agro- processing industries. This course would enable the students to have an idea about the statistical techniques used in quality control. Students who do not have sufficient background of Statistical Methods.

V. Theory

Unit I

Introduction to Statistical Quality Control; Control Charts for Variables – Mean, Standard deviation and Range charts; Statistical basis; Rational subgroups.

Unit II

Control charts for attributes- ‘np’, ‘p’ and ‘c’ charts.

Unit III

Fundamental concepts of acceptance, sampling plans, single, double and sequential sampling plans for attributes inspection.

Unit IV

Sampling inspection tables for selection of single and double sampling plans.

VI. Suggested Reading

- Cowden D.J. 1957. *Statistical Methods in Quality Control*. Prentice Hall of India.
- Dodge H.F. and Romig H.G. 1959. *Sampling Inspection Tables*. John Wiley.
- Duncan A.J. 1986. *Quality Control and Industrial Statistics*. 5th Ed. Irwin Book Co.
- Grant E.L. and Leavenworth R.S. 1996. *Statistical Quality Control*. 7th Ed. McGraw Hill.
- Montgomery D.C. 2008. *Introduction to Statistical Quality Control*. 6th Ed. John Wiley.
- Wetherhil G.B. 1977. *Sampling Inspection and Quality Control*. Halsted Press.

I. Course Title : Optimization Techniques

II. Course Code : STAT 567

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for exposing the students to the mathematical details of the techniques optimization techniques. They will be taught numerical methods of optimization, linear programming techniques, nonlinear programming and multiple objective programming. Students will also be exposed to practical applications of these techniques.

V. Theory

Unit I

Classification of optimization problems, Classical optimization techniques: single variable optimization, multivariable optimization techniques with no constraints, multivariable optimization techniques with equality constraints, multivariable optimization techniques with inequality constraints.

Unit II

Linear programming: simplex method, duality, sensitivity analysis, Karmarkar's method, transportation problem.

Unit III

Nonlinear programming Unconstrained optimization techniques: direct search methods such as random search, grid search, Hooke and Jeeves' method, Powel's method. Descent methods such as gradient method, steepest descent method, conjugate gradient method, Newton's method, Marquardt method.

Unit IV

Quadratic programming, integer linear programming, integer nonlinear programming, geometric programming, dynamic programming, stochastic programming, multiobjective optimization, optimal control theory, genetic algorithms, simulated annealing, neural network based optimization,

VI. Practical

- Problems based on classical optimization techniques, optimization techniques with constraints, minimization problems using numerical methods.
- Linear programming (LP) problems through graphical method, simplex method, simplex two-phase method, primal and dual method.
- Sensitivity analysis for LP problem, LP problem using Karmarkar's method.
- Problems based on Quadratic programming, integer programming, dynamic programming, stochastic programming.
- Problems based on Pontryagin's maximum principle.
- Problems based on multiobjective optimization.

VII. Suggested Reading

- Antunes C.H., Alves, M.J., Climaco J. 2016. *Multi objective Linear and Integer Programming* (EURO Advanced Tutorials on Operational Research)
- Nocedal, J. and Wright, S.J. 1999. *Numerical Optimization*. Springer.
- Rao, S.S. 2007. *Engineering Optimization: Theory and Practice*. New Age International Publishers.
- Rustagi, J.S. 1994. *Optimization Techniques in Statistics*. Academic Press.

- Taha, H.A. 2007. *Operations Research: Introduction with CD*. Pearson Education.
- Xu, H, Teo, K.L. Zhang Y. 2016. *Optimization and Control Techniques and Applications* (Springer Proceedings in Mathematics & Statistics)
- Zeleny, M. 1974. *Linear Multi objective Programming*. Springer.

I. Course Title : Multivariate Analysis

II. Course Code : STAT 571

III. Credit Hours : 2+1

IV. Aim of the course

This course lays the foundation of Multivariate data analysis. Most of the data sets in agricultural sciences are multivariate in nature. The exposure provided to multivariate data structure, multinomial and multivariate normal distribution, estimation and testing of parameters, various data reduction methods would help the students in having a better understanding of agricultural research data, its presentation and analysis.

V. Theory

Unit I

Concept of random vector, its expectation and Variance-Covariance matrix. Marginal and joint distributions. Conditional distributions and Independence of random vectors. Multinomial distribution. Multivariate Normal distribution, marginal and conditional distributions. Sample mean vector and its distribution. Maximum likelihood estimates of mean vector and dispersion matrix. Tests of hypothesis about mean vector.

Unit II

Wishart distribution and its simple properties. Hotelling's T^2 and Mahalanobis D^2 statistics. Null distribution of Hotelling's T^2. Rao's U statistics and its distribution. Wilks' λ criterion and its properties. Concepts of discriminant analysis, computation of linear discriminant function, classification between k (≥ 2) multivariate normal populations based on LDF and Mahalanobis D^2.

Unit III

Principal Component Analysis, factor analysis. Canonical variables and canonical correlations. Cluster analysis: similarities and dissimilarities of qualitative and quantitative characteristics, Hierarchical clustering. Single, Complete and Average linkage methods. K-means cluster analysis.

Unit IV

Path analysis and computation of path coefficients, introduction to multidimensional scaling, some theoretical results, similarities, metric and non-metric scaling methods.

VI. Practical

- Maximum likelihood estimates of mean-vector and dispersion matrix;
- Testing of hypothesis on mean vectors of multivariate normal populations;
- Cluster analysis, Discriminant function, Canonical correlation, Principal component analysis, Factor analysis;
- Multivariate analysis of variance and covariance, multidimensional scaling.

VII. Suggested Reading

- Abdelmonem A, Virginia AC and Susanne M. 2004. *Computer Aided Multivariate Analysis*. Chapman & Hall/CRC.
- Anderson TW. 1984. *An Introduction to Multivariate Statistical Analysis*. 2nd Ed. John Wiley.
- Arnold SF. 1981. *The Theory of Linear Models and Multivariate Analysis*. John Wiley.
- Giri NC. 1977. *Multivariate Statistical Inference*. Academic Press.
- Johnson RA and Wichern DW. 1988. *Applied Multivariate Statistical Analysis*. Prentice Hall.
- Kshirsagar AM. 1972. *Multivariate Analysis*. Marcel Dekker.
- Muirhead RJ. 1982. *Aspects of Multivariate Statistical Theory*. John Wiley. Muirhead, RJ. (2005) *Aspects of Multivariate Statistical Theory*. 2nd Ed. John Wiley.
- Rao CR. 1973. *Linear Statistical Inference and its Applications*. 2nd Ed. John Wiley.
- Rencher AC. 2012. *Methods of Multivariate Analysis*. 3rd Ed. John Wiley.
- Srivastava MS and Khatri CG. 1979. *An Introduction to Multivariate Statistics*. North Holland.

I. Course Title : Regression Analysis

II. Course Code : STAT 572

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant to prepare the students in linear and non-linear regression methods useful for statistical data analysis. They would also be provided a mathematical foundation behind these techniques and their applications in agricultural data.

V. Theory

Unit I

Simple and Multiple linear regressions: Least squares fit, Properties and examples. Polynomial regression: Use of orthogonal polynomials.

Unit II

Assumptions of regression; diagnostics and transformations; residual analysis ~ Studentized residuals, applications of residuals in detecting outliers, identification of influential observations. Lack of fit, Pure error. Test of normality, test of linearity,Testing homoscedasticity and normality of errors, Durbin-Watson test. Test of goodness of fit for the model evaluation and validation.Concept of multi-collinearity

Unit III

Weighted least squares method: Properties, and examples. Box-Cox family of transformations. Use of dummy variables, Over fitting and under fitting of model, Selection of variables: Forward selection, Backward elimination. Stepwise and Stagewise regressions.

Unit IV

Introduction to non-linear models, nonlinear estimation: Least squares for nonlinear models.

VI. Practical

- Multiple regression fitting with three and four independent variables;
- Estimation of residuals, their applications in outlier detection, distribution of residuals;

- Test of homoscedasticity, and normality, Box-Cox transformation;
- Restricted estimation of parameters in the model, hypothesis testing, Step wise regression analysis;
- Least median of squares norm, Orthogonal polynomialfitting.

VII. Suggested Reading

- Barnett V and Lewis T. 1984. *Outliers in Statistical Data*. John Wiley.
- Belsley DA, Kuh E and Welsch RE. 2004. *Regression Diagnostics-Identifying Influential Data and Sources of Collinearity*. John Wiley.
- Chatterjee S and Hadi AS. 2013. *Regression Analysis* by *Example*. A John Wiley & sons Publication.
- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- McCullagh P and Nelder JA. 1999. *Generalized Linear Models*. 2nd Ed.*Chapman* & Hall.
- Montgomery DC, Peck EA and Vining GG. 2003. *Introduction to Linear Regression Analysis*. 3rd Ed. John Wiley.
- Rao CR. 1973. *Linear Statistical Inference and its Applications*. 2nd*Ed*. John Wiley.

I. Course Title : Statistical Computing

II. Course Code : STAT 573

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for exposing the students in the concepts of computational techniques. Various statistical packages would be used for teaching the concepts of computational techniques.

V. Theory

Unit I

Introduction to statistical packages and computing: data types and structures, Use of Software packages like, SAS, SPSS or "R: The R Project for Statistical Computing". Data analysis principles and practice, Summarization and tabulation of data, Exploratory data analysis; Graphical representation of data.Statistical Distributions: Fitting and testing the goodness of fit of discrete and continuous probability distributions;

Unit II

ANOVA, regression and categorical data methods; model formulation, fitting, diagnostics and validation; Matrix computations in linear models. Analysis of discrete data. Multiple comparisons, Contrast analysis.

Unit III

Numerical linear algebra, numerical optimization, graphical techniques, numerical approximations, Time Series Analysis.

Unit IV

Analysis of mixed models; Estimation of variance components, Analysis of Covariance, Fitting of non-linear model, Discriminant function; Principal component analysis. techniques in the analysis of survival data and longitudinal studies, Approaches to handling missing data, and meta-analysis

VI. Practical

- Data management, Graphical representation of data, Descriptive statistics;

- General linear models ~ fitting and analysis of residuals, outlier detection;
- Fitting and testing the goodness of fit of probability distributions;
- Testing the hypothesis for one sample *t*-test, two sample *t*-test, paired *t*-test, test for large samples - Chi-squares test, F test, One way analysis of variance, contrast and its testing, pairwise comparisons;
- Mixed effect models, estimation of variance components;
- Categorical data analysis, dissimilarity measures, similarity measures;
- Analysis of discrete data, analysis of binary data;
- Numerical algorithms;
- Spatial modeling, cohort studies;
- Clinical trials, analysis of survival data;
- Handling missing data.Analysis of time series data - fitting of ARIMA models.

VII. Suggested Reading

- Agresti A. 2013. *Categorical Data Analysis*. 3rd Ed. John Wiley.
- Everitt BS and Dunn G. 1991. *Advanced Multivariate Data Analysis*. 2nd Ed. Arnold.
- Geisser S. 1993. *Predictive Inference: An Introduction*. Chapman & Hall.
- Gelman A & Hill J. 2006. *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge Univ. Press.
- Gentle JE, Härdle W and Mori Y. 2012. *Handbook of Computational Statistics - Concepts and Methods*. 2nd Ed. Springer.
- Han J and Kamber M. 2000. *Data Mining: Concepts and Techniques*. Morgan.
- Hastie T, Tibshirani R and Friedman R. 2001. *The Elements of Statistical Learning: Data Mining, Inference and Prediction*. Springer.
- Kennedy WJ & Gentle JE. 1980. *Statistical Computing*. Marcel Dekker.
- Miller RG Jr. 1986. *Beyond ANOVA, Basics of Applied Statistics*. John Wiley.
- Rajaraman V. 1993. *Computer Oriented Numerical Methods*. Prentice-Hall.
- Ross S. 2000. *Introduction to Probability Models*. Academic Press.
- Ryan BF and Joiner BL. 1994. *MINITAB Handbook*. 3rd Ed. Duxbury Press.
- Simonoff JS. 1996. *Smoothing Methods in Statistics*. Springer.
- Singh, AK. 2016. *Practical R-Book by Examples for Agricultural Statistics*. Deptt. Of Ag. Statistics, IGKV. Raipur
- Snell EJ. 1987. *Applied Statistics: A Handbook of BMDP Analyses*. Chapman & Hall.
- Thisted RA. 1988. *Elements of Statistical Computing*. Chapman & Hall.
- Venables WN and Ripley BD. 1999. *Modern Applied Statistics With S-Plus*. 3rd Ed. Springer.
- http: //www.r-project.org/
- http: //www.stat.sc.edu/~grego/courses/stat706/.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Time Series Analysis

II. Course Code : STAT 574

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant to teach the students the concepts involved in time series data. They would also be exposed to components of time series, stationary models and forecasting/ projecting the future scenarios based on time series data. It would also help them in understanding the concepts involved in time series data presentation, analysis and interpretation.

V. Theory

Unit I

Components of a time-series. Autocorrelation and Partial autocorrelation functions, Correlogram and periodogram analysis.

Unit II

Linear stationary models: Autoregressive, moving average and Mixed processes. Linear non-stationary models: Autoregressive integrated moving average processes.

Unit III

Forecasting: Minimum mean square forecasts and their properties, Calculating and updating forecasts.

Unit IV

Model identification: Objectives, Techniques, and Initial estimates. Model estimation: Likelihood function, Sum of squares function, Least squares estimates. Seasonal models. Intervention analysis models and Outlier detection.

VI. Practical

Time series analysis, autocorrelations, correlogram and periodogram; Linear stationary model; Linear non-stationary model; Model identification and model estimation; Intervention analysis and outlier detection.

VII. Suggested Reading

- Box GEP, Jenkins GM and Reinsel GC. 2007. *Time Series Analysis: Forecasting and Control*. 3rd Ed. Pearson Edu.
- Brockwell PJ and Davis RA. 2002. *Introduction to Time Series and Forecasting*. 2nd Ed. Springer.
- Chatterjee S, Hadi A and Price B.1999. *Regression* Analysis by Examples.John Wiley.
- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Jenkins, GM, Reinsel, GC, Greta M. L,George E.P.B. 2015. *Time Series Analysis: Forecasting and Control*, Wiley Series in Probability and Statistics
- Johnston J. 1984. *Econometric Methods*. McGraw Hill.
- Judge GG, Hill RC, Griffiths WE, Lutkepohl H and Lee TC. 1988. *Introduction to the Theory and Practice of Econometrics*. 2nd Ed. John Wiley.
- Montgomery DC and Johnson LA. 1976. *Forecasting and Time Series Analysis*. McGraw Hill.
- Montgomery DC, Jennings CA and Kulahci M. 2015. *Introduction to Time Series Analysis and Forecasting*, Wiley Series in Probability and Statistics
- Shumway RH and Stoffer DS. 2006. *Time Series Analysis and its Applications: With R Examples*. 2nd Ed. Springer.

I. Course Title : Demography

II. Course Code : STAT 575

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for training the students in measures of demographic indices, estimation procedures of demographic parameters. Students would also be exposed to population projection techniques and principle involved inbioassays.

V. Theory

Unit I

Introduction to vital statistics, crude and standard mortality and morbidity rates, Estimation of mortality, Measures of fertility and mortality, period and cohort measures.

Unit II

Life tables and their applications, methods of construction of abridged life tables, Increment-Decrement Life Tables.

Unit III

Stationary and stable populations, Migration and immigration. Application of stable population theory to estimate vital rates, migration and its estimation. Demographic relations in Nonstable populations. Measurement of population growth, Lotka's model (deterministic) and intrinsic rate of growth, Measures of mortality and morbidityPeriod.

Unit IV

Principle of biological assays, parallel line and slope ratio assays, choice of doses and efficiency in assays quantal responses, probit and logit transformations, epidemiological models.

VI. Suggested Reading

- Cox DR. 1957. *Demography*. Cambridge Univ. Press.
- Charles Griffin. Fleiss JL. 1981. *Statistical Methods for Rates and Proportions*. John Wiley.
- Finney DJ. 1981. *Statistical Methods in Biological Assays*.
- Grow A, Bavel JV. 2016. *Agent-Based Modelling in Population Studies: Concepts, Methods, and Applications* (The Springer Series on Demographic Methods and Population Analysis)
- Lawless JF. 1982. *Statistical Models and Methods for Lifetime Data*. John Wiley.
- MacMahon B and Pugh TF. 1970. *Epidemiology- Principles and Methods.*Little Brown, Boston.
- Mann NR, Schafer RE and Singpurwalla ND. 1974. *Methods for Statistical Analysis of Reliability and Life Data*. John Wiley.
- Newell C. 1988. *Methods and Models in Demography*. Guilford Publ.
- Preston S, Heuveline P and Guillot M. 2001. *Demography: Measuring and Modeling Population Processes*. Blackwell Publ.
- Rowland DT. 2004. *Demographic Methods and Concepts*. Oxford Press.
- Siegel JS and Swanson DA. 2004. *The Methods and Material ofDemography*. 2^{nd} Ed. Elsevier.
- Woolson FR. 1987. *Statistical Methods for the Analysis of Biomedical Data*. JohnWiley.
- Yakovlev AY, Klebanov L and Gaile D. 2013. *Statistical Methods for Microarray Data Analysis: Methods and Protocols* (Methods in Molecular Biology)

I. Course Title : Statistical Methods for Life Sciences

II. Course Code : STAT 576

III. Credit Hours : 2+0

IV. Aim of the course

This course focuses on statistical methods for discrete data collected in public health, clinical and biological studies including survival analysis. This would enable the students to understand the principles of different statistical techniques useful in public health and clinical studies conducted.

V. Theory

Unit I

Proportions and counts, contingency tables, logistic regression models, Poisson regression and log-linear models, models for polytomous data and generalized linear models.

Unit II

Computing techniques, numerical methods, simulation and general implementation of biostatistical analysis techniques with emphasis on data applications. Analysis of survival time data using parametric and non- parametric models, hypothesis testing, and methods for analyzing censored (partially observed) data with covariates. Topics include marginal estimation of a survival function, estimation of a generalized multivariate linear regression model (allowing missing covariates and/or outcomes).

Unit III

Proportional Hazard model: Methods of estimation, estimation of survival functions, time-dependent covariates, estimation of a multiplicative intensity model (such as Cox proportional hazards model) and estimation of causal parameters assuming marginal structural models.

Unit IV

General theory for developing locally efficient estimators of the parameters of interest in censored data models. Rank tests with censored data. Computing techniques, numerical methods, simulation and general implementation of bio-statistical analysis techniques with emphasis on data applications.

Unit V

Newton, scoring, and EM algorithms for maximization; smoothing methods; bootstrapping; trees and neural networks; clustering; isotonic regression; Markov chain Monte Carlomethods.

VI. Suggested Reading

- Biswas S. 2007. *Applied Stochastic Processes. A Biostatistical and Population Oriented Approach*. Wiley Eastern Ltd.
- Collett D. 2003. *Modeling Survival Data in Medical Research*. Chapman & Hall.
- Cox D.R. and Oakes D. 1984. *Analysis of Survival Data*. Chapman & Hall.
- Hosmer DW Jr. and Lemeshow S. 1999. *Applied Survival Analysis: Regression Modeling or Time to Event*. John Wiley.
- Klein J.P. and Moeschberger M.L. 2003. *Survival Analysis: Techniques for Censored and Truncated Data*. Springer.
- Kleinbaum D.G. and Klein M 2005. *Survival Analysis. A Self Learning Text*. Springer.
- Kleinbaum D.G. and Klein M. 2005. *Logistic Regression*. 2nd Ed. Springer.
- Lee ET. 1992. *Statistical Methods for Survival Data Analysis*.
- John Wiley and Miller RG. 1981. *Survival Analysis*. John Wiley.
- Therneau T.M. and Grambsch P.M. 2000. *Modeling Survival Data: Extending the Cox Model*.Springer.

I. Course Title : Statistical Ecology

II. Course Code : STAT 577

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for exposing the students to the importance and use of statistical methods in collections of ecological data, species-abundance relations, community classification and community interpretation.

V. Theory

Unit I

Ecological data, Ecological sampling; Spatial pattern analysis: Distribution methods, Quadrant-variance methods, Distancemethods.

Unit II

Species-abundance relations: Distribution models, Diversity indices; Species affinity: Niche-overlap indices, interspecific association, interspecificcovariation.

Unit III

Community classification: Resemblance functions, Association analysis, Cluster analysis; Community Ordination: Polar Ordination, Principal Component Analysis, Correspondence analysis, Nonlinear ordination.

Unit IV

Community interpretation: Classification Interpretation and Ordination Interpretation.

VI. Suggested Reading

- Gotelli N.J. and Ellison A.M. 2004. *A Primer of Ecological Statistics*
- Pielou E.C. 1970. *An introduction to Mathematical Ecology*. John Wiley.
- Reynolds J.F. and Ludwig J.A. 1988. *Statistical Ecology: A Primer on Methods and Computing*. JohnWiley.
- Young L.J., Young J.H. and Young J. 1998. *Statistical Ecology: A Population Perspective.* Kluwer.

Course Title with Credit load
Ph.D. in Agricultural Statistics

Course Code	Course Title	Credit Hours	Semester
*STAT 601	Advanced Data Analytics	1+2	I
*STAT 602	Simulation Techniques	1+1	I
*STAT 603	Linear Models	2+0	I
*STAT 604	Advanced Statistical Methods	2+1	I
*STAT 611	Baysian Inference	2+0	II
STAT 691	Seminar I	0+1	I
STAT 692	Seminar II	0+1	II
STAT 699	Research	0+75	II-VI
STAT 605	Modeling Techniques for Forecasting	2+1	I
STAT 606	Stochastic Processes	2+0	I
STAT 607	Survival Analysis	2+0	I
STAT 608	Spatial Statistics	1+1	I
STAT 612	Advanced Design of Experiments	2+1	II
STAT 613	Advanced Sampling Techniques	2+1	II
STAT 614	Advanced Statistical Genetics	2+1	II
STAT 615	Advanced Time Series Analysis	2+0	II
STAT 616	Advanced Bioinformatics	2+0	II
STAT 617	Advanced Econometrics	2+0	II
STAT 618	Recent Advances in the Field of Specialization	1+0	II

*Core Courses

Course Contents
Ph.D. in Agricultural Statistics

I. Course Title : Advanced Data Analytics

II. Course Code : STAT 601

III. Credit Hours : 1+2

IV. Aim of the course

This is an advanced course in Statistical Computing that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agricultural sciences and use of statistical packages.

V. Theory

Unit I

Measures of association. Structural models for discrete data in two or more dimensions.

Estimation in complete tables. Goodness of fit, choice of a model. Generalized Linear Model for discrete data, Poisson and Logistic regression models. Log-linearmodels.

Unit II

Elements of inference for cross-classification tables. Models for nominal and ordinal response.

Unit III

Computational problems and techniques for robust linear regression, nonlinear and generalized linear regression problem, tree-structured regression and classification, cluster analysis, smoothing and function estimation, robust multivariate analysis.

Unit IV

Analysis of incomplete data: EM algorithm, single and multiple imputations. Markov Chain, Monte Carlo and annealing techniques, Neural Networks, Association Rules and learning algorithms.

Unit V

Linear mixed effects models, generalized linear models for correlated data (including generalized estimating equations), computational issues and methods for fitting models, and dropout or other missing data.

Unit VI

Multivariate tests of linear hypotheses, multiple comparisons, confidence regions, prediction intervals, statistical power, transformations and diagnostics, growth curve models, dose-response models.

VI. Practical

- Analysis of qualitative data;
- Generalized linear for correlated data;
- Generalized linear models for discrete data;
- Robust methods of estimation and testing of non-normal data;
- Robust multivariate analysis;
- Cluster analysis;
- Analysis of Incomplete data;
- Classification and prediction using artificial neural networks;
- Markov Chain;
- Analysis of data having random effects using Linear mixed effects models;
- Analysis of data with missing observations;
- Applications of multiple comparison procedures;
- Building Simultaneous confidence intervals;
- Fitting of growth curve models to growth data;
- Fitting of dose-response curves and estimation of parameters.

Suggested Reading

- Everitt B.S. and Dunn G. 1991. *Advanced Multivariate Data Analysis*. 2nd Ed. Arnold.
- Geisser S. 1993. *Predictive Inference: An Introduction*. Chapman & Hall.
- Gentle J.E., Härdle W and Mori Y. 2004. *Handbook of Computational Statistics-Concepts and Methods*. Springer.
- Han J and Kamber M. 2000. *Data Mining: Concepts and Techniques*. Morgan.
- Hastie T, Tibshirani R and Friedman R. 2017. *The Elements of Statistical Learning: Data Mining, Inference and Prediction*. Springer. 2nd Ed.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Miller R.G. Jr. 1986. *Beyond ANOVA, Basics of Applied Statistics*. John Wiley.
- Rajaraman V. 1993. *Computer Oriented Numerical Methods*. Prentice-Hall.
- Robert C.P. and Casella G. 2004. *Monte Carlo* Statistical *Methods*. 2nd Ed. Springer.
- Ross S. 2000. *Introduction to Probability Models*. Academic Press.
- Simonoff J.S. 1996. *Smoothing Methods in Statistics*. Springer.
- Thisted R.A. 1988. *Elements of Statistical Computing*. Chapman & Hall.
- Venables W.N. and Ripley B.D. 1999. *Modern Applied Statistics With S-Plus*. 3rd Ed. Springer.
- Free Statistical Softwares: http: //freestatistics.altervista.org/en/stat.php.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Simulation Techniques

II. Course Code : STAT 602

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for students who have a good knowledge in Statistical Inference and Statistical Computing. This course would prepare students for undertaking research in the area of simulation techniques andtheir applications to agricultural sciences.

V. Theory

Unit I

Uses and purposes of simulation; Classification of models. Generation and testing of random numbers, Review of simulation methods; Implementation of simulation methods - for Discrete and continuous probability distribution, sampling and resampling methods: theory and application of the jackknife and thebootstrap.

Unit II

Randomization tests, analysis using computer software packages. Simulating multivariate distributions, MCMC methods and Gibbs sampler.

Unit III

Simulation of generalized linear models and time series models, Simulated data sets to be analyzed using popular computer software packages.

Unit IV

Stochastic simulation: Markov Chain, Monte Carlo, Hastings-Metropolis algorithms, critical slowing-down and remedies, auxiliary variables, simulated tempering, reversible- jump MCMC and multi-grid methods.

VI. Practical

- Simulation from various probability models;
- Resampling methods, jackknife and the bootstrap;
- Randomization tests;
- Simulating multivariate distributions, MCMC methods and Gibbs sampler;
- Simulated data sets to be analyzed using popular computer software packages;
- Markov Chain, Monte Carlo, Gibbs' sampling;
- Reversible- jump MCMC and multi-grid methods.

VII. Suggested Reading

- Averill M.L. 2017. *Simulation, Modeling and Analysis*. Tata McGraw Hill.
- Balakrishnan N, Melas V.B. and Ermakov S. (Ed.). 2000. *Advances in Stochastic Simulation Methods*. Basel-Birkhauser.
- Banks J. (Ed.). 1998. *Handbook of Simulation: Principles, Methodology, Advances, Applications and Practice*. John Wiley.
- Brately P, Fox B.L. and Scharge L.E. 1987. *A Guide to Simulation*. Springer. Davison A.C. and Hinkley D.V. 2003. *Bootstrap Methods and their Application*. Cambridge Univ. Press.
- Gamerman D, Lopes H.F. and Lopes H.F. 2006. *Markov Chain* Monte *Carlo: Stochastic Simulation for Bayesian Inference*. CRC Press.
- Gardner F.M. and Baker J.D. 1997. *Simulation Techniques Set*. John Wiley. Gentle J.E. 2005. *Random Number Generation and Monte Carlo Methods*. Springer.
- Janacek G and Louise S. 1993. *Time Series: Forecasting, Simulation, Applications*. Ellis Horwood Series in Mathematics and its Applications.
- Kleijnen J and Groenendaal W.V. 1992. *Simulation: A Statistical Perspective*. John Wiley.
- Kleijnen J. 1974 (Part I), 1975 (Part II). *Statistical Techniques in Simulation*. Marcel Dekker.
- Law A and Kelton D. 2000. *Simulation Modeling and Analysis*. McGraw Hill.
- Press W.H., Flannery B.P., Tenkolsky S.A. and Vetterling W.T. 1986. *Numerical Recipes*. Cambridge Univ.Press.
- Ripley B.D. 1987. *Stochastic Simulation*. John Wiley. Ross SM. 1997. *Simulation*. John Wiley.

I. Course Title : Linear Models

II. Course Code : STAT 603

III. Credit Hours : 2+0

IV. Aim of the course

The students would be exposed to the theory of linear models, estimation of variance components for unbalanced data and advanced techniques for analysis of data in agriculture.

V. Theory

Unit I

General Gauss Markoff set up, Gauss-Markoff's theorem, Aitken's transformation. Theory of linear estimation, test of hypothesis in linear models. Analysis of variance, partitioning of degrees of freedom. Restricted least squares. Special cases of one and two way classifications (including disproportionate cell frequencies and interaction, cross and nested classifications).

Unit II

Analysis of covariance. Variance components models, estimation of variance components from unbalanced data. Unified theory of least-squares, MINQUE, MIVQUE. Mixed models. LAR, LASSO.

VI. Suggested Reading

- Bapat, R.B. 2012. *Linear Algebra and Linear Models*. Springer-Verlag.
- Graybill, F. A. 1976. *Theory and Application of the Linear Model*. Duxbury, North Scituate.
- Joshi, D.D. 1987. *Linear Estimation and Design of Experiments*. Wiley Eastern.
- Rao, C. R. 2001. *Linear Inference and its Application*. Wiley Eastern.
- Searle, S. R. 1998. *Variance Components*. John Wiley.
- Searle, S.R. 1971. *Linear Models*. John Wiley.
- Seber, G.A. F. 1996. *The Linear Hypothesis: A General Theory*. Griffin, Charles and Co. Ltd.
- Sheffe, H. 1999. *Analysis of Variance*. John Wiley.

I. Course Title : Advanced Statistical Methods

II. Course Code : STAT 604

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Statistical Methods that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agriculturalsciences.

V. Theory

Unit I

Truncated and compound distributions. Fitting of orthogonal polynomials. Pearsonian curves.Categorical data analysis - loglinear models, Association between attributes. Variance stabilizingtransformations.

Unit II

Sampling distribution of correlation coefficient, regression coefficient, correlation ratio, intra class correlation coefficient.

Unit III

Non-central t, χ^2 and F distributions. Distribution of quadratic forms. Cochran's theorem. Tests for normality. Large sample tests. Tests of significance based on t, χ^2 and F distributions. Order statistics, distribution of r^{th} order statistics, joint distribution of several order statistics andtheir functions, marginal distributions of order statistics, distribution of range, median, etc.

Unit IV

Fitting of a generalized linear model, mixed model and variance components estimation, MINQUE, MIVQUE, REML.

VI. Practical

- Fitting of truncated distribution,
- Fitting of Pearsonian curves,
- Analysis of association between attributes, categorical data.
- Fitting of non-central t, χ^2 and F distributions.
- Computation of Tests of significance based on t, χ^2 and F distributions.
- Order statistics.

VII. Suggested Reading

- Chatterjee S, Hadi A and Price B. 2013. *Regression Analysis by Examples*. 5th Ed. John Wiley.
- Draper N.R. and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Rao C.R. 2009. *Linear Statistical Inference and its Applications*. 2nd Ed. John Wiley.
- Searle S.R, Casella G and McCulloch C.E. 1992. *Variance Components*. John Wiley.
- Searle S.R. 1971. *Linear Models*. John Wiley.

I. Course Title : Modeling Techniques for Forecasting

II. Course Code : STAT 605

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Statistical Methods that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in the area of empirical and mechanistic models and nonlinear estimation and the replications in different disciplines of agricultural sciences.

V. Theory

Unit I

Empirical and mechanistic models. Nonlinear growth models: monomolecular, logistic, Gompertz, Richards. Applications in agriculture and fisheries.

Unit II

Nonlinear estimation: Least squares for nonlinear models, Methods for estimation of parameters like Linearization, Steepest, and Levenberg- Marquardt's Parameterization.

Unit III

Two-species systems. Lotka-Volterra, Leslie-Gower and Holling-Tanner non-linear prey-predator models. Volterra's principle and its applications. Gauss competition model.

Unit IV

Compartmental modelling - First and second order input-output systems, Dynamics of a multivariable system.

Unit V

Forecasting techniques with special reference to agriculture. Forecast based on time series data: exponential smoothing, Box – Jenkins approach and non-linear models. Forecast models using weather parameters, crop-weather relationships and their use in yield forecast. Forecast using plant characters.

Unit VI

Forecast surveys, between-year models (regression model, Markov chain probability model and group method of data handling) and within-year models. Agro-meteorological models: climatic water balance model and crop yield assessment. Forewarning of crop pests and diseases. Application of remote sensing techniques in forecasting. Use of ANN in forecasting.

VI. Practical

- Fitting of mechanistic non-linear models;
- Application of Schaefer and Fox non-linear models;
- Fitting of compartmental models.Fitting of forecast models using weather parameters.
- Time series analysis: plots, decomposition, stationarity tests, exponential smoothing. •Univariate Box – Jenkins ARIMA models and seasonal ARIMA models.
- Forecast models using plant characters,
- Agrometeorological models for crop forecasting, Markov chain models and ANN models.

VII. Suggested Reading

- Draper, N.R. and Smith, H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Efromovich S. 1999. *Nonparametric Curve Estimation*. Springer.
- Fan, J. and Yao, Q. 2003. *Nonlinear Time Series-Nonparametric and Parametric Methods*. Springer.
- France, J. and Thornley, J.H.M. 1984. *Mathematical Models in Agriculture*. Butterworths.
- Harvey, A.C. 1996. *Forecasting, Structural Time Series Models and the Kalman Filter*. Cambridge Univ. Press.
- Makridakis, S., Wheelwright, S.C. and Hyndman, R.J. 1998. *Forecasting: Methods and Applications*. John Wiley.
- Pankratz, A. 1983. *Forecasting with Univariate Box Jenkins Models: Concepts and Cases*. John Wiley.
- Thornley, J. and France J. 2006. *Mathematical Models in Agriculture: Quantitative Methods for the Plant, Animal and Ecological Sciences* (Cabi) 2nd Ed.

I. Course Title : Stochastic Processes

II. Course Code : STAT 606

III. Credit Hours : 2+0

IV. Aim of the course

This is a course on Stochastic Processes that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agricultural sciences.

V. Theory

Unit I

Introduction to stochastic process - classification according to state space and time domain. Finite and countable state Markov chains; time- homogeneity; Chapman-Kolmogorov equations, marginal distribution and finite dimensional distributions. Classification of Markov chain. Canonical form of transition probability matrix of a Markov chain. Fundamental matrix; probabilities of absorption from transient states into recurrent classes in a finite Markov chain, mean time for absorption. Ergodic state and Ergodic chain. Stationary distribution of a Markov chain, existence and evaluation of stationary distribution. Random walk and gamblers ruin problem.

Unit II

Discrete state continuous time Markov process: Kolmogorov difference – differential equations. Birth and death process, pure birth process (Yule- Fury process). Immigration-Emigration process. Linear growth process, pure death process.

Unit III

Renewal process: renewal process when time is discrete and continuous. Renewal function and renewal density. Statements of Elementary renewal theorem and Key renewal theorem.

Unit IV

Stochastic process in biological sciences: Markov models in population genetics, compartmental analysis. Simple deterministic and stochastic epidemic model. General epidemic models-Karmack and McKendrick's threshold theorem. Recurrent epidemics.

Unit V

Elements of queueing process; the queuing model M/M/1: steady state behaviors. Birth and death process in queuing theory- Multi channel models. Network of Markovian queuing system.

Unit VI

Branching process: Galton-Watson branching process. Mean and variance of size of nth generation, probability of ultimate extinction of a branching process. Fundamental theorem of branching process and applications.

Unit VII

Wiener process- Wiener process as a limit of random walk. First passage time for Wiener process. Kolmogorov backward and forward diffusion equations and their applications.

VI. Suggested Reading

- Adke SR and Manjunath SM. 1984. *Finite Markov Processes*. John Wiley.
- Bailey NTJ. 1964. *Elements of Stochastic Processes with Applications to the Natural Sciences*. Wiley Eastern.
- Bartlett MS. 1955. *Introduction to Stochastic Processes*. Cambridge Univ. Press.
- Basawa IV and Prakasa Rao BLS. 1980. *Statistical Inference for Stochastic Processes*. Academic Press.
- Bharucha-Reid AT. 2012. *Elements of the Theory of Markov Processes and their Applications*. McGraw Hill.
- Bhat BR. 2000. *Stochastic Models; Analysis and Applications*. New Age.

- Draper NR and Smith H. 1981. *Applied Regression Analysis*. Wiley Eastern. France J &Thornley JHM. 1984. *Mathematical Models in Agriculture*. Butterworths.
- Lawler GF. 2006. *Introduction to Stochastic Processes*. Chapman & Hall. 2nd Ed.
- Medhi J. 2001. *Stochastic Processes*. 2nd Ed. Wiley Eastern.
- Prakasa Rao BLS and Bhat BR.1996. *Stochastic Processes and Statistical Inference*. New Age.
- Ratkowsky DA. 1983. *Nonlinear Regression Modelling: a Unified Practical Approach*. Marcel Dekker.
- Ratkowsky DA. 1990. *Handbook of Nonlinear Regression Models*. Marcel Dekker.
- Seber GAF and Wild CJ. 1989. *Non-linear Regression*. John Wiley.

I. Course Title : Survival Analysis

II. Course Code : STAT 607

III. Credit Hours : 2+0

IV. Aim of the course

The course deals with the study of demographic profiles and survival times. In-depth statistical properties and analysis is an important component of this course.

V. Theory

Unit I

Measures of Mortality and Morbidity: Ratios and proportions, rates of continuous process, rates of repetitive events crude birth rate, Mortality measures used in vital statistics relationships between crude and age specific rates, standardized mortality ratios evaluation of person-year of exposed to risk in long term studies, prevalence and incidence of a disease, relative risk and odds ratio. Survival Distribution: Survival functions, hazard rate, hazard function, review of survival distributions: exponential, Weibull, Gamma, Rayleigh, Pareto, Lognormal~ IFR and TFRA, Gompertz and Makeham. Gompertz and logistic distributions. Parametric (m.l.e) estimation. Types of Censoring: Type I, Type II, random and other types of censoring, right and left truncated distributions. Expectation and variance of future life time, series and parallel system of failures. Life Tables: Fundamental and construction.

Unit II

Complete Mortality data, Estimation of Survival Function: Empirical survival function, estimation of survival function from grouped mortality data, joint distribution of the number of deaths, distribution of the estimation P_i covariance of estimate, estimation of curves of deaths and central death rate and force of mortality rate. Incomplete Mortality data (non-parametric models): Actuarial method, m.1.e method, moment and reduced sample method of estimation and their comparison. Product limit (Kaplan-Meier) method and cumulative hazard function (CHF) of estimation of survival function.

Unit III

Fitting Parametric Survival Distribution: Special form of survival function cumulative hazard function (CHF) plots, Nelson's method of ungrouped data, construction of the likelihood function for survival data, least squares fitting, fitting a Gompertz distribution to grouped data. Some tests of Goodness of fit: Graphical, Kolmogorov-Smirnov statistics for complete, censored and truncated data, Chi-Square test and Anderson- Darling A^2-statistics. Comparison of Mortality

Experiences: Comparison of two life tables, some distribution- free methods (two samples) for ungrouped data, Two samples Kolmogorov-Smirnov test, Wilcoxon test for complete data and modified Wilcoxon test for incomplete data .Gilbert and Gehan's test, mean and variance of Wilcoxon statistics, generalization of Gehan's test. Testing for Consistent Differences in Mortality: Mantel-Haenszel and log rank test. Generalized Mantel-Haenszel test (k-sample).

Unit IV

Concomitant Variables: General parametric model for hazard function with observed concomitant variables. Additive and multiplicative models of hazard rate functions. Estimating multiplicative models, selection of concomitant variables. Logistic linear model, Concomitant Variable regarded as random variable. Age of onset distributions: Models of onset distributions and their estimation. Gompertz distribution, parallel system and Weibull distribution, Fatal short models of failure. Two component series system.

Unit V

Interval Censoring Competing Risk Theory: Indices for measurement of probability of death under competing risks and their inter-relations.Concept of COX regression Stochastic Epidemic Models: Simple epidemic models, general epidemic model definition and concept (without derivation). Duration of an epidemic.

VI. Suggested Reading

- Anderson B. 1990. *Methodological Errors in Medical Research*. Blackwell.
- Armitage P and Berry G. 1987. *Statistical* Methods *in Medical Research*. Blackwell.
- Biswas, S. 2007. *Applied Stochastic Processes*: *A Biostatistical and Population Oriented Approach*, 2nd Ed., New Central Book Agency.
- Collett D. 2014. *Modeling Survival Data in Medical Research*. Chapman & Hall. 3rd Ed.
- Cox D.R. and Oakes D. 1984. *Analysis of Survival Data*. Chapman & Hall.
- Elandt-Johnson R.C. and Johnson N.L. 1980. Survival *Models and Data Analysis*. John Wiley.
- Everitt B.S. and Dunn G. 1998. *Statistical Analysis of Medical Data*. Arnold. Hosmer D.W. Jr. and Lemeshow S. 1999. *Applied Survival Analysis: Regression Modeling or Time to Event*. John Wiley.
- Indrayan, A. 2008. *Medical Biostatistics*, 2nd Ed. Chapman and Hall/CRC.
- Lee E.T. 1980. *Statistical Methods for Survival Data Analysis*. Lifetime Learning Publ.
- Kalbfleisch J.D. and Prentice. R.L. 2002. *The Statistical Analysis of Failure Time Data*. John Wiley.
- Klein J.P. and Moeschberger M.L. 2003. *Survival Analysis: Techniques for Censored and Truncated Data*. Springer.
- Kleinbaum D.G. and Klein M. 2002. *Logistic Regression*.Springer.
- Kleinbaum D.G. and Klein M. 2005. *Survival Analysis*. Springer.

I. Course Title : Spatial Statistics

II. Course Code : STAT 608

III. Credit Hours : 1+1

IV. Aim of the course

This is a course on Spatial statistics aims at exposing the students to some advanced level spatial methods and their applications to agricultural situations.

V. Theory

Unit I

Spatial Analysis and types of spatial data; Visualizing Spatial Data – Exploratory data Analysis.

Unit II

Spatial Relationship- Random forest, spatially autocorrelated data, weight matrix, measures of spatial Auto-correlation – Moran's I & Geary's C; Measuring of autocorrelation of spatially continuous data.

Unit III

Spatial Sampling – Methods and procedures, Statistical Analysis of Spatial Point Process – homogenous Poisson Process, Spatial interpolation – non-statistical methods; Variogram modelling; Spatial Prediction – Simple Kriging, Co-kriging;

Unit IV

Modelling Areal data – Autoregressive and spatial regression models and model diagnostics. Examples of Spatial Data analysis in Agriculture– Disease Mapping; Incorporating spatial effects in Agricultural Field experiments

VI. Practical

- Spatial Data – Import, export;
- Spatial Classes in R;
- Visualizing Spatial Data;
- Spatial Auto-correlation;
- Spatial Sampling, Spatial Interpolation, Spatial Autoregressive Models, Spatial Regression Model

VII. Suggested Reading

- Cressie, N.A.C. 1993.*Statistics for Spatial Data*. Revised Edition. JohnWiley
- Richard E.P. 2018. *Spatial Data Analysis in Ecology and Agriculture Using R*, 2nd Ed.
- Roger S. Bivand, E Pebesma J. and Rubio B.G. 2008. *Applied Spatial Data Analysis using R*. Springer-Verlog.

I. Course Title : Baysian Inference

II. Course Code : STAT 611

III. Credit Hours : 2+0

IV. Aim of the course

This course aims at describing the advanced level topics in statistical methods and statistical inference. This course would prepare students to have a strong base in basic statistics that would help them in undertake basic and applied research in Statistics.

V. Theory

Unit I

Introduction and history and criticism of Bayesian Approach; Subjective interpretation of Probability, Review of Bayes Theorem, Sufficiency, Likelihood Principle.

Unit II

Subjective Prior distribution of a parameter; Posterior Distribution of parameters using Bayes Theorem

Unit III

Informative and non-informative priors for Location and scale; Conjugate families –Discrete and Continuous and interpretation of Hyper-parameters of conjugates.

Unit IV

Non-informative, improper and invariant priors for location and scale and in general settings.

Unit V

Bayesian Point Estimation – squared error loss, absolute error loss etc. Bayesian Interval Estimation – Credible Interval, interpretation and comparison with frequentist confidence Intervals

Unit VI

Bayesian Hypothesis Testing - Specification of the appropriate form of the prior distribution for a Bayesian testing of hypothesis problem. Prior odds, Posterior odds, Bayes factor for various types of testing hypothesis problems

Unit VII

Bayesian Prediction; Numerical and Monte-Carlo Integrations

Unit VIII

Applications of Bayesian Inference - Bayesian Data Analysis

VI. Suggested Reading

- Berger, J.O. 1985. *Statistical Decision Theory and Bayesian Analysis*, Springer Verlag.
- Box, G.P. and Tiao, G.C. 1992. *Bayesian Inference in StatisticalAnalysis*,Addison – Wesley
- Pilon C.D. 2015. *Bayesian Methods for Hackers: Probabilistic Programming and Bayesian Inference* (Addison-Wesley Data and Analytics)

I. Course Title : Advanced Design of Experiments

II. Course Code : STAT 612

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Design of Experiments that aims at describing some advanced level topics for students who wish to pursue research in Design of Experiments. This course prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agricultural sciences.

V. Theory

Unit I

General properties and analysis of block designs. Balancing criteria. m- associate PBIB designs, and their association schemes including lattice designs - properties and construction, Designs for test treatment – control(s) comparisons; Nested block designs, Mating designs.Structurally Incomplete block designs

Unit II

General properties and analysis of two-way heterogeneity designs, Youden type designs, generalized Youden designs, Pseudo Youdendesigns., Designs for two sets of treatments.

Unit III

Balanced factorial experiments - characterization and analysis (symmetrical and asymmetrical factorials). Factorial experiments with extra treatment(s). Orthogonal arrays, Mixed orthogonal arrays, balanced arrays, Fractional replication, Resolution plans, Regular and irregular fractions.

Unit IV

Response surface designs - Symmetrical and asymmetrical factorials, Response optimization and slope estimation, Blocking, Canonical analysis and ridge analysis, CCD, Box-Jenkins, Experiments with mixtures: design and analysis. Experiments with qualitative cum quantitative factors.

Unit V

Optimality criteria and optimality of designs, robustness of designs against loss of data, outliers, etc. Diagnostics in design of experiments.

VI. Practical

Analysis of block designs, Analysis of Latin square type designs, group divisible designs, triangular designs, lattice designs. Analysis of fractional replications of factorial experiments, analysis of asymmetrical factorials and block designs with factorial structure. Analysis of second order response surface designs.

VII. Suggested Reading

- Chakraborti M.C. 1962. *Mathematics of Design and Analysis of Experiments*. Asia Publ.House.
- Dean A.M. and Voss D. 1999. *Design and Analysis of Experiments*.
- pringer. Dey A and Mukerjee R. 1999. *Fractional Factorial Plans*. John Wiley.
- Dey A 1986. *Theory of Block Designs*. Wiley Eastern.
- Hall M Jr. 1986. *Combinatorial Theory*. John Wiley.
- Hedayat A.S., Sloane N.J.A. and Stufken J. 1999. *Orthogonal Arrays: Theory and Applications*. Springer.
- John J.A. and Quenouille M.H. 1977. *Experiments: Design and Analysis*. Charles and Griffin.
- Khuri A.I. and Cornell J.A. 1996. *Response Surface Designs and Analysis*. 2nd Ed. Marcel Dekker.
- Montgomery D.C. 2005. *Design and Analysis of Experiments*. John Wiley.
- Ogawa J. 1974. *Statistical Theory of the Analysis of Experimental Designs*. Marcel Dekker.
- Parsad R, Gupta V.K., Batra P.K., Satpati S.K. and Biswas P. 2007. *Monograph on a-designs*. IASRI, New Delhi.
- Raghavarao D. 1971. *Construction and Combinatorial Problems in Design of Experiments*. John Wiley.
- Shah K.R. and Sinha B.K. 1989. *Theory of Optimal Designs. Lecture notes in Statistics*. Vol. 54. Springer.
- Sharma M.K. 2012. *Design and Analysis of Experiments*. Kindle Ed. 1st Ed.
- Street A.P. and Street D.J. 1987. *Combinatorics of Experimental Designs*.Oxford Science Publ.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Advanced Sampling Techniques

II. Course Code : STAT 613

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Sampling Techniques that aims at describing some advanced level topics for students who wish to pursue research in Sampling Techniques. This course prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to Statistical System in thecountry.

V. Theory

Unit I

Optimum Stratification, two-way stratification, collapsed strata, Controlled selection, Use of combinatorics in controlled selection, Systematic sampling in two dimensions. Sampling with varying probabilities without replacement, Horvitz – Thompson estimator

Unit II

Variance estimation in complex surveys. Taylor's series linearization, balanced repeated replication, Jackknife and bootstrap methods.Ordered and unordered estimators, Sampling strategies, Midzuno-Sen, Rao-Hartley-Cochran,ðPS Sampling: procedures such as Brewer, Durbin and Sampford,

Unit III

Unified theory of sampling from finite populations. UMV - Non-existence theorem and existence theorem under restricted conditions. Concept of sufficiency and likelihood in survey sampling. Admissibility and hyper- admissibility.

Unit IV

Post-stratified estimator, imperfect frames, multiple frames, randomized response techniques. Inference under super population models - concept of designs and model unbiasedness, prediction approach. Regression analysis and categorical data analysis with data from complex surveys. Domain estimation. Small area estimation. Longitudinal survey.

VI. Practical

- Sampling with varying probability,
- Ordered and un-ordered estimators,
- Sampling strategies due to Horvitz-Thompson, Midzuno-Sen, Rao-Hartley-Cochran and PPS sampling: procedures such as Brewer, Durbin and Sampford, etc.
- Imperfect frames, Randomized response technique.
- Small area estimation.

V. Suggested Reading

- Berger J.O. 1993. *Statistical Decision Theory and Bayesian Analysis*. Sringer.
- Bolfarine H and Zacks S. 1992. *Prediction Theory for Finite Population Sampling*. Springer.
- Cassel C.M., Sarndal C.E and Wretman J.H. 1977. *Foundations of Inference in Survey Sampling*. John Wiley.
- Des Raj and Chandhok P. 1998. *Sample Survey Theory*. Narosa Publ.
- House. Ghosh M and Meeden G. 1997. *Bayesian Method for Finite Population*
- *Sampling. Monograph on Statistics and Applied Probability*. Chapman and Hall.

- Mukhopadhyay P. 1998. *Theory and Methods of Survey Sampling*. Prentice Hall of India.
- Rao J.N.K. 2003. *Small Area Estimation*. John Wiley.
- Sarndal C.E., Swensson B and Wretman J.H. 1992. *Model Assisted Survey Sampling*. Springer.

I. Course Title : Advanced Statistical Genetics

II. Course Code : STAT 614

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Statistical Genetics that aims at describing some advanced level topics for students who wish to pursue research in Statistical Genetics. This course prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject in plant and animal breeding.

V. Theory

Unit I

Hardy-Weinberg law with multiple allelic systems, auto-tetraploids and self-sterility alleles. Complex cases of selection with two or more loci.

Unit II

Different approaches to study inbreeding process, methods of path co- efficient, probability and generation matrix. Fisher's approach to inbreeding. Stochastic process of gene frequency change, transition matrix approach using finite Markov chains, diffusion approximation, Steady decay and distribution of gene frequency, Probability of fixation of a gene, Conditional process - Markov chains and diffusion approaches, Distribution of time until fixation, random fluctuations in selection intensity, stationary distribution of gene frequency. Effective population size.

Unit III

Prediction and estimation of genetic merit. Best linear unbiased prediction, Use of mixed model methodology in analysis of animal and plant breeding experiments. Newer reproductive technology and its effect in genetic evaluation of individual merit. Estimation of genetic parameters - problems relating to computational aspects of genetic variance components, parameter estimation in variance component models for binary response data.

Unit IV

Identification of genes with large effects, Use of molecular markers (RFLP, PCR-AFLP, RAPD and SSR), Gene mapping and Quantitative trait loci. Molecular manipulation for genetic variability.

Unit V

Variance component approach and linear regression approach for the analysis of GE interactions.Measurement of stability and adaptability for genotypes. Concepts of general and specific combining ability, diallel and partial diallel crosses: construction and analysis.

VI. Practical

- Hardy-Weinberg law,
- Estimation of genetic load and random genetic drift.
- Effect of finite population size.
- Estimation of path coefficients.
- Detection and estimation of multiple allelism in continuous variation, sexlinked genes, maternal effects.
- Analysis of G × E interaction, measurement of stability and adaptability.
- Analysis of data of diallel and partial diallel crosses.

VII. Suggested Reading

- Crow J.F. and Kimura M. 1970. *An Introduction of Population Genetics Theory*. Harper & Row.
- Ewens W.J. 1979. *Mathematical Population Genetics*. Springer.
- Falconer D.S. 1985. *Introduction to Quantitative Genetics*. ELBL.
- Fisher R.A. 1949. *The Theory of Inbreeding*. Oliver & Boyd.
- Fisher R.A. 1958. *The Genetical Theory of Natural Selection*. Dover Publ.
- Haldane J.B.S. 1932. *The Causes of Evolution*. Harper & Bros.
- Kempthorne O. 1957. *An Introduction to Genetic Statistics*. The Iowa State Univ. Press.
- Lerner I.M. 1950. *Population Genetics and Animal Improvement*. Cambridge Univ. Press.
- Lerner I.M. 1958. *The Genetic Theory of Selection*. John Wiley.
- Li C.C. 1982. *Population Genetics*. The University of Chicago Press.
- Mather K and Jinks J.L. 1982. *Biometrical Genetics*. Chapman & Hall.
- Mather K. 1951. *The Measurement of Linkage in Heredity*.
- Methuen. Nagilaki T. 1992. *Introduction to Theoretical PopulationGenetics*.Springer.
- Narain P. 1990. *Statistical Genetics*. Wiley Eastern.
- Nielsen R, Montgomery S. 2013. *An Introduction to Population Genetics: Theory and Applications* 1st Ed.

I. Course Title : Advanced Time Series Analysis

II. Course Code : STAT 615

III. Credit Hours : 2+0

IV. Aim of the course

This is an advanced course in Time Series Analysis that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agriculturalsciences.

V. Theory

Unit I

Multivariate time series: modelling the mean, stationary VAR models: properties, estimation, analysis and forecasting, VAR models with elements of nonlinearity, Non-stationary multivariate time series: spurious regression, co-integration, Vector Error Correction Model (VECM).

Unit II

Volatility: The class of ARCH and GARCH models; Extensions of GARCH models: TGARCH, IGARCH, PGARCH, EGARCH, GJR-GARCH, ARCH and GARCH model with-t distributed error; ARCD (Auto-Regressive Conditional Density), Multivariate GARCH model: estimation, analysis and forecasting, stochastic volatility.

Unit III

Structural time-series modelling: State space models, Kalman filter, Local level model, Local linear trend model, Seasonal models, Cyclical models. Threshold and Functional coefficient autoregressive models, Structural Break in time series.

Unit IV

Fuzzy time series models, Artificial Neural Network (ANN) methodology, Support vector machines, Wavelets for time series analysis, combinations of time series models.

VI. Suggested Reading

- Box G.E.P., Jenkins G.M. and Reinsel G.C. 2015. *Time Series Analysis: Forecasting and Control*. 5th Ed. John Wiley.
- Brockwell P.J. and Davis R.A. 1991. *Time Series: Theory and Methods*. 2nd Ed. Springer.
- Chatfield C. 2004. *The Analysis of Time Series: An Introduction*. 6th Ed. Chapman& Hall/ CRC.
- Johnston J. 1984. *Econometric Methods*. McGraw Hill.
- Singh, P. 2016. *Applications of Soft Computing in Time Series Forecasting: Simulation and Modeling Techniques*. Springer International Publishing AG
- Tong H. 1995. *Nonlinear Time Series: A Dynamical System Approach*.Oxford Univ. Press.
- Vapnik, V. N. (2000). *The Nature of Statistical Learning Theory*. Springer- Verlag, New York.
- Percival, D.B. and Walden, A.T. 2000. *Wavelet Methods for Time-Series Analysis*. Cambridge University Press, U.K.

I. Course Title : Advanced Bioinformatics

II. Course Code : STAT 616

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Bioinformatics that aims at exposing the students to some advanced statistical and computational techniques related to bioinformatics. This course would prepare the students in understanding bioinformatics principles and their applications.

V. Theory

Unit I

EM algorithm and other statistical methods to discover common motifs in biosequences. Concepts in phylogeny. Gene prediction based on codons, Decision trees, Clustering Techniques, Classificatory analysis, Neural Networks, Genetic algorithms, Pattern recognition, Hidden Markov models.

Unit II

Computational analysis of protein sequence, structure and function. Expression profiling by microarray/ gene chip/ RNAseq, proteomics etc., Multiple alignment of protein sequences, Modelling and prediction of structure of proteins, Designer proteins, Drug designing.

Unit III

Analysis of one DNA sequence (Modeling signals in DNA; Analysis of patterns; Overlaps and Generalizations), Analysis of multiple DNA or protein sequences (Alignment algorithms – Gapped global comparisons and Dynamic programming;

use of linear gap models; protein sequences and substitution matrices – BLOSUM, PAM; Multiple sequences), BLAST (Comparison of two aligned sequences – Parameter calculation; Choice of a score; Bounds for P-value; Normalized and Bit scores, Karlin – Altschul sum statistic; comparison of two unaligned sequences; Minimum significance Lengths).

Unit IV

Markov Chains (MC with no absorbing states, higher order Markov dependence, patterns insequences, Markov Chain Monte Carlo – Hastings-Metropolis algorithm, simulated annealing,MC with absorbing States). Bayesian techniques and use of Gibbs Sampling. Advanced topicsin design and analysis of DNA microarray experiments.

Unit V

Modeling protein families; Multiple sequence alignments; Pfam; Gene finding), Computationally intensive methods (Classical estimation methods; Bootstrap estimation and Confidence Intervals; Hypothesis testing; Multiple Hypothesis testing), Evolutionary models (Models of Nucleotide substitution; Discrete time models – The Jukes-Cantor Model, The Kimura Model, The Felsenstein Model; Continuous-time models)

Unit VI

Phylogenetic tree estimation (Distances; Tree reconstruction – Ultrametric and Neighbor-Joining cases; Surrogate distances; Tree reconstruction; Parsimony and Maximum Likelihood; Modeling, Estimation and Hypothesis Testing;) Neural Networks (Universal Approximation Properties; Priors and Likelihoods, Learning Algorithms – Backpropagation; Sequence encoding and output interpretation; Prediction of Protein Secondary Structure; Prediction of Signal Peptides and their cleavage sites; Application for DNA and RNA Nucleotide Sequences), Analysis of SNPs and Haplotypes.

VI. Practical

- Genomic databases and analysis of high-throughput data sets, BLAST and related sequence comparison methods.
- Statistical methods to discover common motifs in biosequences.
- Multiple alignment and database search using motif models, clustalw, classificatory analysis, neural networks, genetic algorithms, pattern recognition,
- Hidden Markov models.
- Computational analysis of protein sequence.
- Expression profiling by microarray/ gene chip, proteomics.
- Modelling and prediction of structure of proteins.
- Bayesian techniques and use of Gibbs Sampling.
- Analysis of DNA microarray experiments.
- Analysis of one DNA sequence, multiple DNA or protein sequences.
- Computationally intensive methods, multiple hypothesis testing,
- Phylogenetic tree estimation,
- Analysis of SNPs and haplotypes.

VII. Suggested Reading

- Baldi P and Brunak S. 2001. *Bioinformatics: The Machine Learning Approach*. MIT Press.
- Baxevanis AD and Francis BF. (Eds.). 2004. *Bioinformatics: A Practical Guide to the Analysis*

of Genes and Proteins. John Wiley.
- Duda RO, Hart PE and Stork DG. 1999. *Pattern Classification*. John Wiley.
- Ewens WJ and Grant GR. 2001. *Statistical Methods in Bioinformatics*.Springer.
- Jones NC and Pevzner PA. 2004. *Introduction to Bioinformatics Algorithms*. The MIT Press.
- Koskinen T. 2001. *Hidden Markov Models for Bioinformatics*. Kluwer.
- Krane DE and Raymer ML. 2002. *Fundamental Concepts of Bio-informatics*.
- Benjamin/ Cummings.
- Krawetz SA &Womble DD. 2003. *Introduction to Bioinformatics: A Theoretical and Practical Approach*. Humana Press.
- Lesk AM. 2002. *Introduction to Bio-informatics*. Oxford Univ. Press.
- Linder E and Seefeld K. 2005. *R for Bioinformatics*. O'Reilly and Associates.
- Percus JK. 2001. *Mathematics of Genome Analysis*. Cambridge Univ. Press.
- Sorensen D and Gianola D. 2002. *Likelihood, Bayesian and MCMC Methods in Genetics*. Springer.
- Tisdall J.D. 2001. *Mastering Perl for Bioinformatics*. O'Reilly & Associates.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. *Data Mining in Bioinformatics*. Springer.
- Wu C.H. and McLarty J.W. 2000. *Neural Networks and Genome Informatics*. Elsevier.
- Wunschiers R. 2004. *Computational Biology Unix/Linux, Data Processing and Programming*. Springer.
- Yang M.C.C. 2000. *Introduction to Statistical Methods in Modern Genetics*. Taylor & Francis.

I. Course Title : Advanced Econometrics

II. Course Code : STAT 617

III. Credit Hours : 1+1

IV. Aim of the course

This is a course on Econometrics aims at exposing the students to some advanced level econometric methods and their applications to agricultural situations.

V. Theory

Unit I

Quantile regression, binary quantile regression, extreme values, copula, loss functions, Point and interval forecasting, unconditional and conditional forecasting, forecasting with serially correlated errors, bootstrap: asymptotic expansion, bootstrap consistency, asymptotic refinement, recent developments for dependent timeseries. Co integration analysis.

Unit II

Multivariate time series: modelling the mean, stationary VAR models: properties, estimation, analysis and forecasting, VAR models with elements of nonlinearity, Non-stationary multivariate time series: spurious regression, co-integration, common trends; Volatility: Modelling the variance, The class of ARCH models: properties, estimation, analysis and forecasting, stochastic volatility, realized volatility.

Unit III

Basic Concepts of Bayesian Inference, Probability and Inference, Posterior Distributions and Inference, Prior Distributions. The Bayesian linear model and autoregressive (AR) processes; Model selection with marginal likelihoods and fractional priors, Comparison of Bayesian Methods with Classical approaches, Bayes risk and their applications, and Sample Selection Monte Carlo integration, importance sampling and Gibbs sampling, The Regression Model with General

Error Covariance Matrix, Qualitative Choice Models, Bayesian information criterion (BIC), Markov Chain Monte Carlo (MCMC) Model Composition and stochastic search variable selection, BUGS [Bayesian Inference Using Gibbs Sampling], BUCC [Bayesian Analysis, Computation and Communication].

VI. Practical

Fitting of equation with serially correlated errors, ordinary least-squares and generalized least squares methods of estimation. Non-stationary multivariate time series analysis. Fitting of The Regression Model with General Error Covariance Matrix, Qualitative Choice Models, Bayesian information criterion (BIC), Markov Chain Monte Carlo (MCMC) Model Composition and stochastic search variable selection, BUGS Fitting of ARCH model.

VII. Suggested Reading

- Banerjee A, Dolado J, Galbraith J and Hendry D.F. 1993. *Co-integration, Error Correction, and the Econometric Analysis of Nonstationary Data*. Oxford Univ. Press.
- Bauwens L, Lubrano M. and Richard J.F. 1999. *Bayesian Inference in Dynamics of Econometric Models*. Oxford Univ. Press.
- Carlin B.P. and Louis T.A. 2008. *Bayes and Empirical Bayes Methods for Data Analysis*. Chapman & Hall.
- Gilks W.R., Richardson S and Spiegelhalter D. 1996. *MCMC in Practice*.Chapman & Hall.
- Greenberg E. 2012. *Introduction to Bayesian Econometrics*. Cambridge Univ. Press.
- Hamilton J.D. 1994. *Time Series Analysis*. Princeton Univ. Press.
- Judge G.G., Griffith W.E., Hill R.C., Lee C.H. and Lutkepohl H. 1985. *The Theory and Practice of Econometrics*. 2nd Ed. JohnWiley.
- Koop G, Poirier D and Tobias J. 2007. *Bayesian Econometric Methods*.Cambridge Univ. Press.
- Koop G. 2003. *Bayesian Econometrics*. John Wiley.
- Lancaster A. 2004. *An Introduction to Modern Bayesian Econometrics*. Blackwell.
- Pindyck R.S. and Rubinfeld D.L. 1981. *Econometric Models and Economic Forecasts*. McGraw Hill.

I. Course Title : Recent Advances in the Field of Specialization

II. Course Code : STAT 618

III. Credit Hours : 1+0

IV. Aim of the course

To familiarize the students with the recent advances in the areas of their specialization to prepare them for undertaking research.

V. Theory

Recent advances in the field of specialization - sample surveys / design of experiments /statistical genetics / statistical modeling / econometrics / statistical inference, etc. will be covered by various speakers from the University / Institute as well as from outside the University / Institute in the form of seminar talks.

VI. Suggested Reading

Recent journals related to the research works.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Statistical Sciences
– Computer Application

Course Title with Credit Load
M.Sc. (Ag) in Computer Application

Course Code	Course Title	Credit Hours	Semester
*MCA 513	Mathematics for Applied Sciences	2+0	I
*MCA 514	Statistical Computing	1+1	III
*MCA 551	Mathematical Foundations in Computer Science	3+0	I
*MCA 552	Object Oriented Programming	2+1	I
*MCA 553	Design And Analysis of Algorithms	2+1	I
*MCA 561	Data Structures	2+1	II
*MCA 562	System Software and Programming	2+1	II
*MCA 563	Internet Technologies	1+1	II
*MCA 571	Database Management Systems	2+1	III
*MCA 572	Software Engineering	2+0	III
MCA 591	Master's Seminar	0+1	I/II/III
MCA 599	Master's Research	0+30	II-IV
MCA 554	Information Security	2+0	I
MCA 555	Web Technologies and Applications	1+1	I
MCA 556	Computer Networks	2+0	I
MCA 564	Bioinformatics Computing	1+1	II
MCA 565	Soft Computing Techniques	1+1	II
MCA 573	Operating System	2+1	III
MCA 574	Compiler Construction	2+1	III
MCA 575	Data Warehousing and Data Mining	2+1	III
	Supporting Courses		
MCA 501	Computers Fundamentals and Programming	2+1	I
MCA 502	Computer Organization Andarchitecture	2+0	I
MCA 511	Introduction Tocommunication Technologies, Computer Networking and Internet	1+1	II
MCA 512	Information Technology in Agriculture	2+0	II

*Core Courses

Course Contents
M.Sc. (Ag) in Computer Application

I. Course Title : Computer Fundamentals and Programming

II. Course Code : MCA 501

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Computer Fundamentals and Programming that aims at exposing the students to understand how computer works, analytical skills to solve problems using computers. andto write computer programs using C.

V. Theory

Unit I

Functional units of computer, I/O devices, primary and secondary memories. Number systems: decimal, octal, binary and hexadecimal; Representation of integers, fixed and floating point numbers, Operator precedence, character representation; ASCII, Unicode.

Unit II

Programming Fundamentals with C - Algorithm, techniques of problem solving, flowcharting, stepwise refinement; Constants and variables; Data types: integer, character, real, data types; Arithmetic expressions, assignment statements, logical expressions. Control flow

Unit III

Arrays and structures. Pointers, dynamic memory allocations

Unit IV

Program Structures – functions, subroutines

Unit V

I/O operations, Program correctness; Debugging and testing of programs.

VI. Practical

- Conversion of different number types;
- Creation of flow chart, conversion of algorithm/flowchart to program;
- Mathematical operators, operator precedence;
- Sequence, control and iteration;
- Arrays and string processing;
- Matrix operations, Sorting, Pointers and File processing – Reading and writing text files.

VII. Suggested Reading

- Balaguruswamy E. 2019. *Programming with ANSI C*. Tata McGraw Hill.
- Gottfried B. 2017. *Programming with C, Schaum Outline Series*. Tata McGraw Hill.
- Kanetkar Y. 1999. *Let Us C*. BPB Publ.

- Malvino A.P. and Brown J.A.. 2017. *Digital Computer Electronics*. Tata McGrawHill.
- Mano M.M. 1999. *Digital Logic and Computer Design*. Prentice Hall of India.

I. Course Title : Computer Organization and Architecture
II. Course Code : MCA 502
III. Credit Hours : 2+0

IV. Aim of the course

This is a course on Computer Organization and Architecture that aims at exposing the students to understand basic knowledge of how computer works.

V. Theory

Unit I

Number systems; Boolean algebra - minimization of Boolean function using KarnaughMap.

Unit II

Logic Gates, Combinational circuits – multiplexer, de-multiplexer, encoder, decoder; Sequential circuits: Flip-flops, Half and Full adder, Shift register, Counters.

Unit III

Organization of CPU, Control Unit- Instruction and Execution cycle in CPU, Register Organization, The Instruction Cycle, Instruction Pipelining.

Unit IV

Memory organization - Internal memory: Semiconductor Main Memory (RAM, ROM, EPROM), Cache Memory, Advanced DRAM Organization; External Memory - Magnetic Disks, RAID, Optical Memory, Magnetic Tape.

Unit V

Basic structure of computer hardware and system software - Addressing methods and machine programme sequencing; Input-output organizations - accessing I/O devices - direct memory access (DMA) – interrupts.

Unit VI

Introduction to microprocessors – CISC and RISC Architecture, Study of functional units of microprocessors.

VI. Suggested Reading

- Gear C.W. 1974. *Computer Organization and Programming*. McGraw Hill.
- Hayes J.P. 1988. *Computer Architecture and Organisation*. McGraw Hill.
- Malvino A.P and Brown J.A. 1999. *Digital Computer Electronics*. Tata McGraw Hill.
- Mano M.M. 1999. *Digital Logic and Computer Design*. Prentice Hall of India.
- Mano M.M. 2007. *Computer System Architecture*. Prentice Hall of India.
- Stallings W. 2016. *Computer Organization and Architecture: Designing for Performance*. Pearson Edu.

I. Course Title : Introduction to Networking and Internet Applications
II. Course Code : MCA 511
III. Credit Hours : 1+1

IV. Aim of the course

This is a course on Introduction to Networking and Internet Applications that aims at exposing the students to understand Computer networking and web applications development.

V. Theory

Unit I

Networking fundamentals, types of networking, network topology; Introduction to File Transfer Protocol (FTP), Telnet, Simple Mail Transfer Protocol (SMTP), Internet Protocol v4 & v6. Network infrastructure and Security-switches, routers, firewall, intranet, internet, Virtual Private Network

Unit II

World Wide Web (www), working with Internet; Web pages, web sites, web servers; Web Applications.

Unit III

Hyper Text Markup Language (HTML), DHTML, web based application development. Static websites, dynamic websites. Client Side processing – scripting languages, Jquery. Server Side processing ASP.NET/JSP

VI. Practical

- Network and mail configuration;
- Using Network Services;
- Browsing of Internet;
- Creation of web pages;
- Creation of websites using HTML and scripting languages.

VII. Suggested Reading

- Cox V, Wermers L and Reding E.E. 2006. *HTML Illustrated Complete*. 3rd Ed. Course Technology.
- Niederst J. 2001. *Web Design in a Nutshell*. O'Reilly Media.
- Tanenbaum A.S. 2003. Computer Networks. *Prentice* Hall of India.

I. Course Title : Information Technology in Agriculture

II. Course Code : MCA 512

III. Credit Hours : 2+0

IV. Aim of the course

This is a course on Introduction to Networking and Internet Applications that aims at exposing the students to understand analogy of computer, basic knowledge of MS Office. Also to understand Internet and WWW, use of IT application and different IT tools in Agriculture

V. Theory

Unit I

Introduction to Computers, Anatomy of computer, Operating Systems, definition and types, Applications of MS Office for document creation & Editing, Data presentation, interpretation and graph creation, statistical analysis, mathematical expressions,

Unit II

Database, concepts and types, uses of DBMS in Agriculture, World Wide Web

(WWW): Concepts and components, Introduction to computer programming languages, concepts and standard input/output operations. e-Agriculture, concepts and applications,

Unit III

Use of ICT in Agriculture, Computer Models for understanding plant processes. IT application for computation of water and nutrient requirement of crops, Computer-controlled devices (automated systems) for Agri-input management, Smartphone Apps in Agriculture for farm advises, market price, postharvest management etc.,

Unit IV

Geospatial technology for generating valuable agri-information. Decision support systems, concepts, components and applications in Agriculture, Agriculture Expert System, Soil Information Systems etc. for supporting Farm decisions, Preparation of contingent crop-planning using IT tools.

VI. Suggested Reading

- Vanitha G. 2011. *Agro-informatics*
- http://www.*agrimoon*.com
- http://www.agriinfo.in
- http://www.eagri.org
- http://www.agriglance.com
- http://agritech.tnau.ac.in

I. Course Title : Mathematics for Applied Sciences

II. Course Code : MCA 513

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for students who do not have sufficient background of Mathematics. The students would be exposed to elementary mathematics that would prepare them to study their main courses that involve knowledge of Mathematics. The students would get an exposure to Linear Algebra, differentiation, integration and differential equations etc.

V. Theory

Unit I

Set theory-set operations, finite and infinite sets, operations of set, function.

Unit II

Vectors and vector spaces, Matrices notations and operations, laws of matrix algebra; transpose and inverse of matrix, Eigen values and Eigen vectors. Determinants - evaluation and properties of determinants, Solutions of Linear Equations.

Unit III

Variables and functions, limits and continuity of specific functions. Differentiation: theorems of differentiation, differentiation of logarithmic, trigonometric, exponential and inverse functions, Differentiation of function of a function, derivatives of higher order, partial derivatives. Application of derivatives, determination of points of inflexion, maxima and minima.

Unit IV

Integration, methods of integration, reduction formulae, definite and indefinite integral, Applications of integration in Agriculture, Differential Equations.

VI. Suggested Reading

- Hohn FE. 2013. *Elementary Matrix Algebra*, 3rdEd., Kindle Edition
- Harville DA. 1997. *Matrix Algebra from a Statistician's Perspective*. Springer.
- Searle SR. 1982. *Matrix Algebra Useful for Statistics*. John Wiley.
- Stewart J. 2007. *Calculus*. Thompson.
- Thomas GB. Jr. and Finney RL. 1996. *Calculus.* 9th Ed. Pearson Edu

I. Course Title : Statistical Computing

II. Course Code : MCA 514

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for exposing the students in the concepts of computational techniques. Various statistical packages would be used for teaching the concepts of computational techniques.

V. Theory

Unit I

Introduction to statistical packages and computing: data types and structures, Use of Software packages like, SAS, SPSS or "R: The R Project for Statistical Computing". Data analysis principles and practice, Summarization and tabulation of data, Exploratory data analysis; Graphical representation of data.Statistical Distributions: Fitting and testing the goodness of fit of discrete and continuous probability distributions;

Unit II

ANOVA, regression and categorical data methods; model formulation, fitting, diagnostics and validation; Matrix computations in linear models. Analysis of discrete data. Multiple comparisons, Contrast analysis

Unit III

Numerical linear algebra, numerical optimization, graphical techniques, numerical approximations, Time Series Analysis

Unit IV

Analysis of mixed models; Estimation of variance components, Analysis of Covariance, Fitting of non-linear model, Discriminant function; Principal component analysis. techniques in the analysis of survival data and longitudinal studies, Approaches to handling missing data, and meta-analysis

VI. Practical

- Data management, Graphical representation of data, Descriptive statistics
- General linear models ~ fitting and analysis of residuals, outlier detection
- Fitting and testing the goodness of fit of probability distributions
- Testing the hypothesis for one sample *t*-test, two sample *t*-test, paired *t*-test, test for large samples - Chi-squares test, F test
- One way analysis of variance, contrast and its testing, pairwise comparisons

- Mixed effect models, estimation of variance components
- Categorical data analysis, dissimilarity measures, similarity measures
- Analysis of discrete data, analysis of binary data
- Numerical algorithms
- Spatial modeling, cohort studies
- Clinical trials, analysis of survival data
- Handling missing data
- Analysis of time series data - fitting of ARIMA models.

VII. Suggested Reading

- Agresti A. 2013. *Categorical Data Analysis*. 3rd Ed. John Wiley.
- Everitt B.S. and Dunn G. 1991. *Advanced Multivariate Data Analysis*. 2nd Ed. Arnold.
- Geisser S. 1993. *Predictive Inference: An Introduction*. Chapman & Hall.
- Gelman A and Hill J. 2006. *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge Univ. Press.
- Gentle J.E., Härdle W and Mori Y. 2012. *Handbook of Computational Statistics - Concepts and Methods*. 2nd Ed. Springer.
- Han J and Kamber M. 2000. *Data Mining: Concepts and Techniques*. Morgan.
- Hastie T, Tibshirani R and Friedman R. 2001. *The Elements of Statistical Learning: Data Mining, Inference and Prediction*. Springer.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Miller RG Jr. 1986. Beyond ANOVA, *Basics of Applied Statistics*. John Wiley.
- Rajaraman V. 1993. *Computer Oriented Numerical Methods*. Prentice-Hall.
- Ross S. 2000. *Introduction to Probability Models*. Academic Press.
- Ryan B.F. and Joiner B.L. 1994. *Minitab Handbook*. 3rd Ed. Duxbury Press.
- Simonoff J.S. 1996. *Smoothing Methods in Statistics*. Springer.
- Singh, AK. 2016. *Practical R-Book by Examples for Agricultural Statistics*. Deptt. of Ag. Statistics, IGKV. Raipur
- Snell E.J. 1987. Applied Statistics: A Handbook of BMDP Analyses. Chapman & Hall.
- Thisted R.A. 1988. Elements of Statistical Computing. Chapman & Hall.
- Venables W.N. and Ripley B.D. 1999. Modern Applied Statistics With S-Plus. 3rd Ed. Springer.
- http://www.r-project.org/
- http://www.stat.sc.edu/~grego/courses/stat706/.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Mathematical Foundations in Computer Science

II. Course Code : MCA 551

III. Credit Hours : 3+0

IV. Aim of the course

This is a course on Mathematical Foundations in Computer Science that aims at exposing the students to provide basic foundations in Mathematics for problem solving.

V. Theory

Unit I

Mathematical Logic: Propositions – Simple and complex; Validity of Proposition-Truth Tables; Use of Propositions in computer programming.

Unit II

Mathematical data types: Sets, Functions, Bijective functions, pigeon-hole principle, Boolean functions, permutation functions, Boolean algebra, recursion relations.

Unit III

Number Theory: Binary arithmetic, exponentiation, induction, sequences, big-oh notation, GCD, Euclidean algorithm, partially ordered sets, congruence and equivalence relation, encryption scheme, Fibonacci sequence, linear homogenous recurrence relations with constant coefficients.

Unit IV

Matrix Algebra Basic operations on matrices, Rank and inverse of matrices. System of linear equations, Characteristic roots and equations, Eigen values and eigen vectors;

Unit V

Graph Theory: Graphs, trees, LAN, Eulerian cycles, Hamiltonian cycles, graph coloring, graph algorithms.

VI. Suggested Reading

- Abertson M.O. and Hutchinson J.P. 1988. *Discrete Mathematics with Algorithms*. John Wiley.
- Deo N. 1984. *Graph Theory with Application to Engineering and Computer Science*. Prentice Hall of India.
- Knuth D.E. 2011. *Art of Computer Programming*. Vol. I. *Fundamental Algorithms*. Addison Wesley.
- Tremblay J.P. and Manohar R.P. 2017. *Discrete Mathematical Structures with Applications to Computer Science*. McGraw Hill.

I. Course Title : Object Oriented Programming

II. Course Code : MCA 552

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Java that aims at exposing the students to understand basic concepts of object oriented design and to write computer programs for problem solving using object oriented.

V. Theory

Unit I

Introduction to Objected Oriented Programming(OOP), Introduction to C++, data types in C++, Compilation and execution of C++; data types, control flow, input/output operations, interaction with file systems – reading, writing and appending.

Unit II

Strings, string manipulations, Arrays, functions, scope of variables, structures in C++.

Unit III

Classes, data members, member functions, this Pointer, Friends, Friend Functions, Friend Classes, Constructors, destructors.

Unit IV

Operator Overloading, dynamic binding, parametric polymorphism. Inheritance, inheritance and dynamic binding, multiple inheritance.

Unit V

New Approaches to programming – Model-View-Controller (MVC) architecture, Single page applications.

VI. Practical

- Case studies using object oriented analysis and design (OOAD);
- Creation of classes with features - overloading, inheritance, data abstraction, polymorphism and Implementation of a case study.

VII. Suggested Reading

- Arnold K and Gosling J. 1996. *The Java Programming Language. The Java Series*. Addison Wesley.
- Bergin J. 1994. *Data Abstraction: The Object-Oriented Approach Using C++*. McGraw Hill.
- Holzner S. 1997. *The Visual C++ Programming Language*. Prentice Hall of India.
- Johnsonbaugh R and Kalin M. 1995. *Object Oriented Programming in C++*. Prentice Hall.
- Khoshafian S and Abnous R. 1995. *Object Orientation Concepts, Languages, Databases, User Interfaces*. JohnWiley.
- Sengupta S and Korobkin C.P. 1994. *C++ Object Oriented Data Structures*.Springer.
- Stroustrup B. 1997. *The C++ Programming Language*. Addison Wesley.
- Troelsen A. 2005. *Pro C# 2005 and the .NET 2.0 Platform*. 3rd Ed. Apress.
- Kothari D.P. 2013. *Object Oriented Approach using C++*

I. Course Title : Design and Analysis of Algorithms

II. Course Code : MCA 553

III. Credit Hours : 2+1

IV. Aim of the course

This course provides a theoretical foundation in designing algorithms. The focus is on the advanced analysis of algorithms and on how the selections of different data structures affect the performanceof algorithms.

V. Theory

Unit I

Algorithm Analysis – Time Space Tradeoff – Asymptotic Notations – Conditional asymptotic notation – Removing condition from the conditional asymptotic notation - Properties of big-Oh notation – Recurrence equations – Solving recurrence equations – Analysis of linear search.

Unit II

Divide and Conquer: General Method – Binary Search – Finding Maximum and Minimum –Merge Sort – Greedy Algorithms: General Method – Container Loading – Knapsack Problem.

Unit III

Dynamic Programming: General Method – Multistage Graphs – All-Pair shortest paths – Optimal binary search trees – 0/1 Knapsack – Travelling salesperson problem.

Unit IV

Backtracking: General Method – 8 Queens problem – sum of subsets – graph coloring – Hamiltonian problem – knapsack problem.

Unit V

Graph Traversals – Connected Components – Spanning Trees – Biconnected components – Branch and Bound: General Methods (FIFO & LC) – 0/1 Knapsack problem – Introduction to NP-Hard and NP-Completeness.

VI. Practical

- Solving recurrence equations, Analysis of linear search,
- Programming Divide and Conquer Algorithms and their analysis,
- Programming Greedy Algorithms and their analysis,
- Implementing Dynamic Programming and their analysis,
- Implementing Backtracking examples,
- Implementing Graph Traversals,
- Implementing Spanning Trees.

VII. Suggested Reading

- Alfred V. Aho, John E. Hopcroft and Jeffrey D. Ullman. 1999. *The Design and Analysis of Computer Algorithms*. Pearson Education.
- Cormen, T.H., C.E. Leiserson, R.L. Rivest, and C. Stein. 2003. *Introduction to Algorithms*. Prentice Hall of India, New Delhi.
- Horowitz E, Sahni S and Rajasekaran S. 2007. *Computer Algorithms/ C++*. Universities Press.

I. Course Title : Information Security

II. Course Code : MCA 554

III. Credit Hours : 2+0

IV. Aim of the course

This course provides exposure to challenges and techniques for securing the information in servers and Web enabled systems. The course deals with theoretical as well as practical issues of Information Security.

V. Theory

Unit I

General introduction to security, Cryptographic techniques: classical cryptography, conventional cryptography (DES), public-key cryptography (RSA), and digital signatures (DSA), steganography.

Unit II

Security services: message integrity, confidentiality and authentication, certification and key management (PKI).

Unit III

Network security applications: IP security (IPsec), Web security (SSL, TLS, SET), Electronic mail security (PGP, S/MIME), and SNMP security.

Unit IV

Access control in computer networks: authentication protocols and services (Kerberos), firewalls and Virtual Private Networks (VPNs).

Unit V

System security: intrusion detection, viruses. E-commerce securities: e-payment systems, fair data exchange.

VI. Suggested Reading

- Amoroso E. 1994. *Fundamentals of Computer Security Technology*. Prentice-Hall.
- Bhushan M. 2017. *Fundamentals of Cyber Security* Prentice Hall
- Chapman B and Zwicky E.D. 2000. *Building Internet Firewalls*. O'Reilly.
- Ford W. 1994. *Computer Communications Security*. Prentice Hall. Pfleeger CP. 2006. *Security in Computing*. Prentice Hall.
- Stallings W. 2003. *Cryptography and Network Security: Principles and* Practice. Prentice-Hall.

I. Course Title : Web Technologies and Applications

II. Course Code : MCA555

III. Credit Hours : 1+1

IV. Aim of the course

The main objective of the course is to introduce the whole range of web technologies. Through the various examples, the course will describe how to design a specific page, dynamic web pages, forms and frames and interaction with adatabase.

V. Theory

Unit I

Survey of contemporary Internet Technologies - Role, use and implementation of currenttools.

Unit II

Application Layer Services and protocols - Domain name services, network management protocol, electronic mail and file transfer protocol.

Unit III

World Wide Web – Web pages, Web Sites, Web Servers; Intranet andxtranet Concepts; Web Application Architectures.

Unit IV

Hyper Text Markup Language (HTML); Building static and dynamic web pages.

Unit V

Scripting Languages - Client side and server side scripting; Interaction with database.

Unit VI

Latest trends in programming on the emerging technologies relating to web based software development.

VI. Practical

- Designing static website with features like tables, hyperlink among pages, pictures, frames and layers;
- Client side scripting for user interface validation;
- Server side scripting for database interaction;
- Designing of a information system.

VII. Suggested Reading

- Ayers D, Bergsten H, Bogovich M, Diamond J, Ferris M, Fleury M, Halberstadt A, Houle P, Mohseni P, Patzer A, Philips R, Li S, Vedati K, Wilcox M and Zeiger S. 1999. *Professional Java Server Programming*. Wrox Press Ltd.

- Boudreaux 2005. PHP 5: *Your Visual Blueprint for Creating Open Source, Server-side Content*. (Visual Blueprint). Visual.
- Ellis M.D. 2007. *ASP.NET AJAX Programming Tricks*. Magma Interactive.
- Esposito D 2007. *Introducing Microsoft ASP. NET AJAX (Pro Developer)*. Microsoft Press.
- Evjen B, Hanselman S and Rader D. 2008. *Professional ASP.NET 3.5: In C# and VB* (*Programmer to Programmer*). Wrox Press Ltd.
- Haefel-Monson R. 2003. *Enterprise JavaBeans*. O'Reilly & Associates.
- Naughton P and Schildt H. 2001.*The Complete Reference, Java 2*. TataMcGraw Hill.
- Neimke D. 2006. *ASP.NET 2.0 Web Parts in Action: Building Dynamic Web Portals (In Action)*. Manning Publ.
- Walther S. 2008. ASP.NET 3.5 Unleashed. Sams.

I. Course Title : Computer Networks

II. Course Code : MCA 556

III. Credit Hours : 2+0

IV. Aim of the course

This course addresses the principles, architectures and protocols that have gone into the development of the Internet and modern networked applications. The course examines network design principles, underlying protocols, technologies and architectures such as naming, data transport, routing and algorithms for networked applications including messaging, encryption and authentication.

V. Theory

Unit I

The importance of Networking, Types of Networking, Network Topology, Transmission Media, Data communication: Concepts of data, signal, channel, bandwidth, bit-rate and baud-rate; Maximum data-rate of channel; Analog and digital communications, asynchronous and synchronous transmission.

Unit II

Network adapters card, Multiplexer (FDM, TDM, STDM), Hub, Repeater. Network References Models: Layered architecture, protocol hierarchies, interface and services.

Unit III

ISO-OSI references model, TCP/IP reference model; Data link layer function and protocols: Framing, error-control, flow control; sliding window protocol; HDLC, SLIP and PPP protocol.

Unit IV

Network layer - routing algorithms, congestion control algorithms; Internetworking: bridges and gateway; Transport layer - connection management, addressing; Flow control and buffering, multiplexing.

Unit V

Session layer – RPC; Presentation layer - abstract syntax notation.

Unit VI

Application layer - File Transfer Protocol (FTP), Telnet, Simple Mail Transfer Protocol (SMTP); World Wide Web(WWW) - Wide Area Indexed Servers (WAIS), WAP; Network Security; Data compression and cryptography.

VI. Suggested Reading

- Arick MR. 1994. *The TCP/IP Companion - A Guide for Common User*. Shroff Publ.
- Freer J. 1990. *Computer Communication and Networks*. Affiliated East West Press.
- Hayes J. 2001. *Modelling and Analysis of Computer Communication Networks*. KhannaPubl.
- Tanenbaum AS. 2003. *Computer Networks*. Prentice Hall of India.

I. Course Title : Data Structures

II. Course Code : MCA 561

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Data Structures that aims at exposing the students tounderstand data structures and their use in problem solving and to analyze different algorithms

V. Theory

Unit I

Algorithms and analysis of Algorithms, Big Oh notation. Arrays, Linked Lists, Elementary List Processing. Memory Allocation for Lists. Strings. Compound Data Structures.

Unit II

Recursive algorithms, Divide and conquer, Dynamic programming, Trees, different tree traversal algorithms, graph traversal.

Unit III

Sorting, Selection Sort. Insertion Sort. Bubble Sort. Performance Characteristics of Elementary Sorts. Shellsort. Sorting Other Types of Data. Index and Pointer Sorting. algorithms.

Unit IV

Quick sort, merging, merge sort, Heap structure, algorithm on heap structure, Queues, priority queues, Search Algorithms

VI. Practical

Implementation of various types of structures - linked lists, doubly linked lists, circular linked lists, queue, dequeue, stack and tree; String processing; Searching and sorting techniques; Graph and geometric algorithms and Casestudies

VII. Suggested Reading

- Aho A.V., Hopcroft J.E. and Ullman J.D. 1983. *Data Structures and Algorithms*. Addison Wesley.
- Cormen T.H., Leiserson CE, Rivest R.L. and Stein C. 2006. *Introduction toAlgorithms*. Prentice Hall of India.
- Goodrich M.T., Tamassia R and Mount D. 2004. *Data Structures and Algorithms in* C^{++}. John Wiley.
- Horowitz E and Sahani S. 1983. *Fundamentals of Data Structures*. Galgotia Publ.
- Jain H. 2018. *Problem Solving in Data Structures and Algorithms Using Java.*
- Kleinberg J and Tardos E. 2006. *Algorithm Design*. Pearson Edu.
- Knuth D.E. 1968. *Art of Computer Programming*. Vol. I. *Fundamental Algorithms*. Addison Wesley.
- Knuth D.E. 1973. *Art of Computer Programming*. Vol. III. *Sorting and Searching*. Addison Wesley.

- Kruse R.L. and Ryba A.J. 1998. *Data Structures and Program Design in C^{++}*. Prentice-Hall.
- Langsam Y, Augenstein M.J. and Tanenbum A.S. 1999. *Data Structures Using C and C^{++}*. Prentice Hall of India.
- Tremblay J.P. and Sorenson P.G. 2017. *An Introduction to Data Structures with Applications*. McGrawHill.
- Weiss M.A. 1994. *Data Structures and Algorithm Analysis in C^{++}*. Benjamin/Cummings.

I. Course Title : System Software and Programming

II. Course Code : MCA 562

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on System Software and Programming that aims at exposing the students to understand operating systems and its functions and to design and write simple low level programming.

V. Theory

Unit I

Systems software-introduction, system specific features; Operating Systems and its functions – device management, process management, memory management, file system management, security.

Unit II

Users, directory, files, file access rights; Terminal Controls and signals; Modularization and program assembly – Interfaces, APIs, header files, libraries, shared objects, dynamic and static links.

Unit III

Input/output at System Level – sequential and random access; indexes.

Unit IV

Memory Management –Allocating and deallocating memory; Threads, spawning processes, network access, sleep, Inter Process communications – pipes, shared memory, sockets, secured sockets, Certificates.

Unit V

Object oriented software design; Generic and reusable classes, Debugging and testing of programs

VI. Practical

- Low Level programming for input/output interface, memory, threads, listening and responding,
- Programming constructs, control statements: branching and looping, file operations,
- Creation of classes with features - overloading, inheritance, data abstraction, polymorphism and a case study using and Object oriented language.

VII. Suggested Reading

- Ken A and Gosling, J. 1996. *The Java Programming Language*. The Java Series. Addison Wesley.
- Balaguruswamy, E. 2019. *Programming with ANSI C*. Tata McGraw Hill, New Delhi.
- Balaguruswamy, E. 2017. *Programming with Object Oriented Programming using C++*. Tata McGraw Hill, New Delhi.

- Bergin, J. 1994. *Data Abstraction: The Object-Oriented Approach Using C++*. McGraw Hill.
- Sethi, R. 1996. *Programming Language Concepts*. Addison Wesley.
- Stroustrup, B. 1997. *The C++ Programming Language*. Addison Wesley.

I. Course Title : Internet Technologies

II. Course Code : MCA 563

III. Credit Hours : 1+1

IV. Aim of the course

The main objective of the course is to introduce the whole range of web technologies. Through the various examples, the course will describe how to design a specific page, dynamic web pages, forms and frames and interaction with adatabase.

V. Theory

Unit I

World Wide Web – Web pages, Web Sites, Web Servers; Intranet and Extranet Concepts; Hyper Text Markup Language (HTML); Building static dynamic web pages.

Unit II

Web application architecture – (ASP.NET/Java) – Web Forms, Server Side Controls, handling events, Validation, JQuery

Unit III

Database Connectivity, read, write, update databases using web forms; data bound controls, sessions, session handling

Unit IV

Authentication of users, Personalization, Roles, role based access

Unit V

Using external libraries/ controls; Ajax, Jquery; Data Exchange – XML, JSON; Creating web services

VI. Practical

- Designing static website with features like tables, hyperlink among pages, pictures, frames and layers;
- Client side scripting for user interface validation;
- Server side scripting for database interaction;
- Designing of information system.

VII. Suggested Reading

- Ayers D, Bergsten H, Bogovich M, Diamond J, Ferris M, Fleury M, Halberstadt A, Houle P, Mohseni P, Patzer A, Philips R, Li S, Vedati K, Wilcox M and Zeiger S. 1999. *Professional Java Server Programming*. Wrox Press Ltd.
- Buest C and Allamaraju S. 2007. *Professional Java Server Programming*: J2EE 3rd Ed.
- Boudreaux 2005. PHP 5: *Your Visual Blueprint for Creating Open Source, Server-side Content*. (Visual Blueprint). Visual.
- Ellis M.D. 2007. *ASP.NET AJAX Programming Tricks*. Magma Interactive.
- Esposito D. 2007. *Introducing Microsoft ASP.NET AJAX* (*Pro-Developer*). Microsoft Press.
- Evjen B, Hanselman S and Rader D. 2008. *Professional ASP.NET 3.5: In C# and VB* (*Programmer to Programmer*). Wrox Press Ltd.
- Haefel-Monson R. 2003. *Enterprise Java Beans*. O'Reilly & Associates.

- Naughton P and Schildt H. 2001. *The Complete Reference, Java 2*. Tata McGraw Hill.
- Neimke D. 2006. *ASP.NET 2.0 Web Parts in Action: Building Dynamic Web Portals* (*In Action*). Manning Publ.
- Walther S. 2008. *ASP.NET 3.5 Unleashed*. Sams.

I. Course Title : Bioinformatics Computing

II. Course Code : MCA 564

III. Credit Hours : 1+1

IV. Aim of the course

The aim of the course is to introduce modern computational practices in bioinformatics at the algorithmic level that will train the students to complement researchers with biological background.

V. Theory

Unit I

The Central Dogma, Review and Utilization of Biological Databases.

Unit II

Overview of Algorithms: Pattern Matching, Biological Motivation Naïve Algorithm.

Unit III

Pre-processing: Suffix trees Time and Space Considerations. Approximate Pattern Matching: Sequence Comparisons, Dot Plots. Sequence Alignment: Dynamic Programming, Global and Local Alignments Scoring Matrices, BLAST, FASTA Parameters.

Unit IV

Similarity and Distance: PAM & BLOSUM matrices, Heuristic Approaches.

Unit V

Exhaustive Search Fragment Assembly: DNA Sequencing, Greedy Algorithms, Sequencing by Hybridization Fragment Assembly.

Unit VI

Graph Algorithms, Overlap Graphs, and Hamiltonian Path Wrap-up.

VI. Practical

- Suffix trees: Time and Space Considerations;
- Approximate Pattern Matching: Sequence Comparisons, Dot Plots;
- Sequence Alignment: Dynamic Programming, Global and Local Alignments Scoring Matrices, BLAST, FASTA Parameters;
- Similarity and Distance: PAM & BLOSUM matrices,
- Heuristic Approaches and Exhaustive Search Fragment Assembly: DNA Sequencing, Greedy Algorithms, Sequencing by Hybridization Fragment Assembly,
- Graph Algorithms, Overlap Graphs, and Hamiltonian PathWrap-up.

VII. Suggested Reading

- Bryan B. 2002. *Bioinformatics Computing*. Prentice Hall.
- Duda R.O., Hart P.E. and Stork D.G. 1999. *Pattern Classification*. John Wiley.
- Ewens W.J. and Grant G.R. 2001. *Statistical Methods in Bioinformatics*. Springer.
- Jones N.C. and Pavel A.P. 2004. *Introduction to Bioinformatics Algorithms*. MIT Press.
- Koskinen T. 2001. *Hidden Markov Models for Bioinformatics*. Kluwer.

- Krane D.E. & Raymer M.L. 2002. *Fundamental Concepts of Bioinformatics*. Benjamin / Cummings.
- Krawetz S.A. and Womble D.D. 2003. *Introduction to Bioinformatics: A Theoretical and Practical Approach*. Humana Press.
- Lesk A.M. 2002. *Introduction to Bioinformatics*. Oxford Univ. Press.
- Shortliffe E.H. and Cimino J.J. 2006. *Biomedical Informatics: Computer Applications in Health Care and Biomedicine* (*Health Informatics*). Springer.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. *Data Mining in Bioinformatics*. Springer.

I. Course Title : Soft Computing Techniques

II. Course Code : MCA 565

III. Credit Hours : 1+1

IV. Aim of the course

This course introduces the soft computing techniques and their applications in solving real world problems. The course is dealt with the perspective of using soft computing techniques in machine learning.

V. Theory

Unit I

Introduction to soft-computing tools – Fuzzy Logic, Genetic Algorithm, Neural Networks and Probabilistic Reasoning, Rough Sets.

Unit II

Applications of Fuzzy Logic concepts in Knowledge Management.

Unit III

Optimization problem solving using genetic algorithm.

Unit IV

Neuron as a simple computing element, the perceptron, multilayer neural networks, Neural network approaches in data analysis, design and diagnostics problems; Applications of probabilistic reasoning approaches.

VI. Practical

Classification using Fuzzy Logic, Genetic Algorithm, Neural Networks

VII. Suggested Reading

- Goldberg D.E. 2008. *Genetic Algorithms in Search, Optimization, and Machine Learning*. Addison Wesley.
- Haykin S. 1998. *Neural Networks: A Comprehensive Foundation*. Prentice Hall.
- Jang J.R., Sun C and Mizutani E. 1996. *Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence*. Prentice Hall.
- Kecman V and Kecman V. 2001. *Learning and Soft Computing: Support Vector Machines, Neural Networks, and Fuzzy Logic Models*. MIT Press.
- Lee K.H. 2005. *First Course on Fuzzy Theory and Applications*. Springer.
- Mitra S and Acharya T. 2003. *Data Mining: Multimedia, Soft Computing, and Bioinformatics*. John Wiley.

I. Course Title : Database Management System

II. Course Code : MCA 571

III. Credit Hours : 2+1

IV. Aim of the course

Database systems are backbone of any information system, enterprise resource planning, research activities and other activity that require permanence of data storage. This course provides the basic introduction to database system technologies; design, concurrency, security and backup/recovery issues of database management systems. The major focus in this course is the Relational database model.

V. Theory

Unit I

Database system - Operational Data, Characteristics of database approach, architecture.

Unit II

Overview of DBMS; Data associations - Entities, Attributes and Associations, Relationship among Entities, Representation of Associations and Relationship, Data Model classification.

Unit III

Entity Relationship model; Relational Data Structure- Relations, Domains and Attributes, Relational Algebra and Operations, Retrieval Operations.

Unit IV

Relational Database Design - Anomalies in a Database, Normalization Theory, and Normal forms; Query processing.

Unit V

Distributed Databases- concepts, architecture, design; Structured Query Language (SQL) - Data Definition Language (DDL), Data Manipulation Language (DML).

Unit VI

PL/SQL - Stored procedure, Database triggers; Relational Data Base Management Package.

VI. Practical

E-R diagram construction; SQL - Command Syntax, Data types, DDL Statements, DML Statements, integrity constraints; Triggers, creating stored procedures/ functions; Normalization of database and Case study on a database design andimplementation.

VII. Suggested Reading

- Date C.J. 2000. *Introduction to Database System*. Addison Wesley.
- Desai B.C. 2000. *Introduction to Database Systems*. Galgotia Publ.
- Elmasri and Navathe. 2006. *Fundamentals of Database Systems*. 4th Ed. Addison Wesley.
- Garcia-Molina H., Ullman J.D. and Widom J. 2013. *Database Systems: The Complete Book*. Prentice Hall.
- Rob P. and Coronel C. 2006. *Database Systems: Design, Implementation and Management*. 7th Ed. Thomson Learning.
- Silberschartz A, Korth H.F. and Sudarshan S. 1997. *Database Systems Concepts*. Tata McGraw Hill.

I. Course Title : Software Engineering

II. Course Code : MCA 572

III. Credit Hours : 2+0

IV. Aim of the course

The objective of the course is to make the learner efficiently work as software engineer so as to acquaint them with all the phases of Software Development Life Cycle.

V. Theory

Unit I

Software engineering definition; Software Development: Phases, Process models, Project structure, Project team structure, Role of metrics, Measurement, Software quality factors.

Unit II

Planning and Software Project: Requirement analysis, Cost estimation, Project Scheduling, Quality Assurance Plan, and Project Monitoring Plans, Gantt charts, PERT and CPM.

Unit III

System Design: Design Objectives, Design Principles, Design Tools, and Techniques, Prototyping.

Unit IV

Structured Programming Coding: Programming Practices, Verification, Monitoring and Control.

Unit V

Testing: Testing Fundamentals, Functional Testing, Structural Testing, Test Plan activities, Unit testing, IntegrationTesting.

Unit VI

Reliability: Concept of Software Reliability, Reliability Models, Limitations of Reliability Models, Software Maintenance. CASE tools.

VI. Suggested Reading

- Aggarwal K.K. and Singh Y. 2006. *Software Engineering*. 2nd Ed. New Age.
- Awad E.M. 1993. *System Analysis and Design*. Galgotia Publ.
- Fairley R. 2017. *Software Engineering Concepts*. Tata McGraw Hill.
- Jalote P. 2005. *An Integrated Approach to Software Engineering*. 3rd Ed. Narosa.
- Kerzner H. 1998. *Project Management: A System Approach to Planning, Scheduling and Controlling*. CBS.
- Mall R. 2006. *Fundamentals of Software Engineering*. 2nd Ed. Prentice- Hall ofIndia.
- Pressman R.S. 2017. *Software Engineering: A Practitioner's Approach*. 6th Ed. McGraw Hill.
- Sommerville I. 2004. *Software Engineering*. 6thEd. Pearson Edu.

I. Course Title : Operating System

II. Course Code : MCA 573

III. Credit Hours : 2+1

IV. Aim of the course

The main objective of this course is to provide core knowledge of Operating Systems features,functions and techniques.

V. Theory

Unit I

Operating system overview: operating system as an extended machine and resource manager; Operating system classifications; Operating system modes and system calls.

Unit II

Operating system architecture; Process model, Process synchronization, Concurrent processes,Process scheduling criterion and algorithms.

Unit III

Problem of mutual exclusion; Deadlock and prevention; Race conditions; Semaphores; Monitors; Process allocation.

Unit IV

Memory management; Multi-programming with fixed and variable number of tasks; Continuousallocation; Paging, Demand paging, Page fault; Virtual memory; Fragmentation; Segmentedmemory management, shared segments; Segmented and demand paged management, Overlaysand swapping, Thrashing.

Unit V

Multi-processor system, Master slave scheduling; Homogeneous scheduling; Device managementsystem; Dedicated share and virtual devices.

Unit VI

File Management System- Input-Output file protection; Remote Procedure Call; Distributedoperating system (Course to be taught in accordance to the Unix Operating System).

VI. Practical

- Problems using system calls for process management, signaling, file management, directorymanagement, protection;
- Critical section problem; Solution to mutual exclusion by Peterson method;
- Producer consumer problem with fatal race conditions;
- Comparison of various CPU scheduling algorithms and Paging, segmentation and demand paging.

VII. Suggested Reading

- Bach, M.J. 2015. *Design of the UNIX Operating System*. Pearson Education.
- Deitel, H.M. 1990. *An Introduction to Operating System*. Addison Wesley.
- Dhamdhere, D.M. 2007. *Operating Systems: A Concept Based Approach*. Tata McGraw Hill, NewDelhi.
- Kernighan, B.W. and Pike, R. 1996. *The UNIX Programming Environment*. Prentice Hall of India,New Delhi.
- Peterson, J. and Silberschatz, A. 1991. *Operating System*. Addison Wesley.
- Stallings, W. 2006. *Operating Systems: Internals and Design Principals*. Prentice Hall of India, New Delhi.
- Silberchatz, A., Galvin, P.B. and Gagne, G. 2006. *Operating System Principals*. Wiley India.
- Tanenbaum, A.S. 2001. *Modern Operating Systems*. Prentice Hall of India, New Delhi.

I. Course Title : Compiler Construction

II. Course Code : MCA 574

III. Credit Hours : 2+1

IV. Aim of the course

The purpose of the course is to acquaint various phases of compiler writing which will help anapplication/system programmer working on other projects besides compilers.

V. Theory

Unit I

Introduction to Compiler, Compilation Process, Compiler Structure.

Unit II

Programming Language Grammars, Elements of a Formal Language Grammar, Derivation,Reduction and Syntax Trees, Ambiguity Regular Grammar & Regular Expression – Context FreeGrammar.

Unit III

Introduction to Finite Automata, Deterministic Finite Automata.

Unit IV

Non-deterministic Finite Automata; Scanning & Parsing Techniques – The Scanner, RegularGrammar and FSA, Top Down Parsing, Parsing Algorithm, Top Down Parsing WithoutBacktracking, Predictive Parsers, Bottom Up Parsing, Parsing, LR Parsers, Shift Reduce Parsing; Symbol Table.

Unit V

Organization, Memory Allocation – Static & Dynamic Memory Allocation, Compilation Control Transfer, Procedure Calls, Conditional Execution, Iteration Control Construct; Lexical Syntax Errors, Semantic, Major Issues in Optimization, Optimizing.

Unit VI

Transformations, Local Optimization, Program Flow Analysis, Global Optimization.

VI. Practical

- Design of a lexical analyser for regular expression;
- Design of a finite state machine;
- Program for - magic squares, context free grammar, shift reduce parsing, operator precedence parsing, recursive decent parsing, predictive parser, simple LR parser and Post fix form for intermediate code.

VII. Suggested Reading

- Aho, A.V. and Ullman, J.D. 1993. *Principles of Compiler Design Theory*. NarosaPublishing House,New Delhi.
- Galles, G. 2007. *Modern Compiler Design*. Pearson Education.
- Holab, A. 2006. *Compiler Design in C*. Prentice-Hall of India, New Delhi.
- Lewis, P.M., Rosenkrantz, D.J. and Stearns, R.E. 1978. *Compiler Design Theory*. Addison Wesley.
- Tremblay, J.P. and Sorenson, P.G. 1985. *The Theory and Practice of Compiler Writing*. McGraw Hill.
- Raghavan V. 2017. *Principles of Compiler Design*. Addison Wesley

I. Course Title : Data Warehousing and Data Mining

II. Course Code : MCA 575

III. Credit Hours : 2+1

IV. Aim of the course

The basic objective of this course is to familiarize students about this state of art of setting datawarehouse for business intelligence in relation to agricultural research, development and planning.

V. Theory

Unit I

Concepts and principles of data warehousing; Project management and requirements. Introduction to Data Mining and its Tasks, Data Pre-processing, Data Discretization

Unit II

Dimensional modelling; Data warehousing architecture; System process and process architecture. Classification and Prediction, Decision Tree, Naive Bayes' Classifier.

Unit III

Data warehousing design; Database schema; Data staging. Output and Knowledge Representation, Evaluation and Credibility, Association Rule Mining.

Unit IV

Partitioning strategy; Aggregations; Data marts; Meta data management; OLAP Modelling, Querymanagement. Clustering: Similarity measures, Hierarchical Clustering, k-Means Clustering.

Unit V

Data warehouse security; Backup and recovery; Building end-user Applications; Capacity planning; Testing the warehouse.

Unit VI

Implementation and maintenance of data warehouse; Case study.

V. Practical

- Data warehouse design, selection of schema;
- Normalization and renormalization;
- Query planstrategy;
- Performance tuning, backup and recovery of data warehouse;
- Dynamic reports and OLAP Reports.
- Introduction to Data Mining software,
- Data Pre-processing, Discretization, Decision Tree: D3,Naïve Bayes' Classifier,
- Association Rule Mining: Apriori Algorithm,
- Clustering: Hierarchical Clustering, K-Means.

VI. Suggested Reading

- Gupta, G.K. 2014. *Introduction to Data Mining with Case Studies*. Prentice Hall of India, New Delhi.
- Han, J and Kamber, M. 2006. *Data Mining: Concepts and Techniques*. Morgan Kaufman.
- Inmon, B. 2005. *Building the Data Warehouse*. John Wiley.
- Kelly, S. 1997. *Data Warehousing in Action*. John Wiley.
- Kimball, R. 2000. *The Data Webhouse Toolkit: Building the Web-Enabled Data Warehouse*. John Wiley.

- Kimball, R. 2002. *The Data Warehouse Toolkit: The Complete Guide to Dimensional Modeling*. John Wiley.
- Kimball, R. 2004. *The Data Warehouse ETL Toolkit: Practical Techniques for Extracting, Cleaning, Conforming, and Delivering Data*. John Wiley.
- Kimball, R. 2005. *The Microsoft Data Warehouse Toolkit: With SQL Server 2005 and the Microsoft Business Intelligence Toolset*. John Wiley.
- Kimball, R. 2008. *The Data Warehouse Lifecycle Toolkit: Practical Techniques for Building Data Warehouse and Business Intelligence Systems.* John Wiley.
- Kimball, R and Ross M. 2013. *The Data Warehouse Toolkit: The Complete Guide to Dimensional Modeling*, John Wiley
- Lee, K.H. 2005. First Course on Fuzzy *Theory and Applications*. Springer.

Course Title with Credit Load
Ph.D. in Computer Application

Course Code	Course Title	Credit Hours	Semester
*MCA 601	Spatial Informatics, GIS and Remote Sensing	1+1	I
*MCA 602	Introduction to Computer Graphics	1+1	I
*MCA 611	Computer Oriented Numerical Analysis	2+1	II
*MCA 612	Artificial Intelligence and Machine Learning	2+1	II
*MCA 615	Bioinformatics Computing	2+0	II
MCA 691	Seminar I	0+1	I/II
MCA 692	Seminar II	0+1	I/II
MCA 699	Research	0+75	II-VI
MCA 603	Simulation and Modeling	1+1	I
MCA 604	Introduction to Big Data	2+1	I
MCA 605	Introduction to Iot	2+1	I
MCA 606	Management Information Systems	2+0	I
MCA 613	Multimedia And its Applications	1+1	II
MCA 614	Knowledge Based Systems for Semantic Web	1+1	II

*** Core Course**

Course Contents
Ph.D. in Computer Application

I. Course Title : Spatial Informatics, GIS and Remote Sensing Techniques

II. Course Code : MCA 601

III. Credit Hours : 1+1

IV. Aim of the course

The basic objective of this course is to teach concepts of GIS and remote sensing with specific applications in agriculture related statistics.

V. Theory

Unit I

Introduction to Geographical Information System (GIS); Introduction- maps and spatial information, components of a GIS; GIS Internals - data representation- raster and vector data structures and analysistechniques.

Unit II

Digital Elevation Models; Data input, verification, storage and output.

Unit III

Spatial modelling- manual and automatic digitizing process; Data errors in GIS; Classification methods-multivariate analysis and classification.

Unit IV

Spatial interpolation; Current and potential uses of GIS in agricultural planning; Software components used in GIS; GIS in India.

Unit V

Physics of remote sensing, atmospheric effects and remote sensing sensors; Spectral signatures of earth surface features, spectral characteristics of vegetation, soil and water.

Unit VI

Data acquisition system, satellite image acquisition; Data collections: pre- processing and data storage; Visual and digital image interpretation; Digital image processing.

VI. Practical

- Digitization of a map with the help of a digitizer;
- Map editing;
- Geo- referencing and map projections;
- Creation of attribute database and linking with spatial data;
- General analysis of the data with the help software;
- Applications of digital elevation models using GIS;
- Spatial interpolations using GIS;
- Visual interpretations of remote sensing data;

- Geometric corrections of remote sensing digital data;
- Methods for improving quality of digital data and Techniques of image classifications.

VII. Suggested Reading

- Annadurai S and Shanmugalakshmi R. 2007. *Fundamentals of Digital Image Processing*. Pearson Edu.
- Burrough P.A. 1986. *Principles of Geographic Information System for Land Resources Assessment*. Oxford Univ. Press.
- Curran P.J. 1985. *Principles of Remote Sensing*. Longman.
- Jensen J.R. 2017. *Introductory Digital Image Processing*. 4^{th} Ed. Prentice Hall.
- Lillesand T.M. and Kiefer R.W. 1987. *Remote Sensing and Image Interpretation*. John Wiley.
- Peuquet D.J. and Marble D.F. 1990. *Introductory Readings in Geographic Information System*. Taylor & Francis.

I. Course Title : Introduction to Computer Graphics

II. Course Code : MCA 602

III. Credit Hours : 1+1

IV. Aim of the course

This course examines the principles of computer graphics, with a focus on the mathematics and theory behind 2D and 3D graphics rendering.

V. Theory

Unit I

Introduction, Application of Graphics, Elements of Graphics Workstation, Graphics I/P Devices; Development of computer graphics: Basic graphics system and standards.

Unit II

Raster scan and random scan graphics; Continual refresh and storages displays; Display processors and character generators; Colour display techniques.

Unit III

Frame buffer and bit operations, Concepts in raster graphics; Points, Lines and Curves; Scan conversion; Line-drawing algorithms; Circle and ellipse generation; Polygon filling; Conic-section generation.

Unit IV

Antialiasing; Two-dimensional viewing: Basic transformations; Co- ordinate systems; Windowing and clipping; Segments; Interactive picture- construction techniques; Interactive input/output devices.

Unit V

Three-dimensional concepts: 3-D representations and transformations; 3-D viewing; Algorithm for 3-D volumes, Spline curves and surfaces.

Unit VI

Fractals; Quadtree and Octree data structures; Hidden line and surface rendering and animation.

VI. Practical

- Implementation of algorithms for drawing geometrical figures, rotation, charts;

- Pixel handling on screen;
- Clipping – Line clipping – Polygon Clipping, Windowing;
- Use of primitive transformations and/or their combinations;
- Implementation of 3D Object Representation and Fractal programming and animation.

VII. Suggested Reading

- Hearn D and Baker M.P. 2004. *Computer Graphics*. Prentice Hall of India. Marshal G. 1983. *Programming with Graphics*. Granada Publ.
- Newman W.M. and Sproull R.F. 1981. *Principles of Interactive Computer Graphics*. McGrawHill.
- Prince D.M. 1979. *Interactive Graphics for Computer Aided Design* (*CAD*). Addison Wesley.
- Rogers D.F. 2001. *Procedural Elements in Computer Graphics*. McGraw Hill.
- Shalini G.P. 2010. *Principles of Computer Graphics: Theory and Practice Using OpenGL and Maya*. McGraw Hill.

I. Course Title : Simulation and Modeling

II. Course Code : MCA 603

III. Credit Hours : 1+1

IV. Aim of the course

The courses aim at teaching simulation and modeling technique for conducting experiments on models that describe the behaviour, uncertainty and structure of real world systems. This course will help in simulation of agricultural research problems and systems.

V. Theory

Unit I

Uses and purposes of simulation; Classification of models.

Unit II

Generation and testing of random numbers.

Unit III

Simulation of stochastic events and processes, Discrete event simulation.

Unit IV

Design of simulation experiments. Analysis of data generated by simulation experiments. Verification and validation of simulation models.

Unit V

Simulation languages.

Unit VI

Simulation of agricultural problems and systems.

VI. Practical

- Generation of random numbers;
- Testing randomness of generated random numbers;
- Generation of random variates following Normal, Beta, Gamma, Exponential, Chi-square, Student's-t, F, Weibull, Binomial, Poisson distributions with the given parameters;

- Discrete event simulation and Simulation from specific models applicable in agriculture.

VII. Suggested Reading

- Averill M.L. and Kelton D. 2005. *Simulation, Modelling and Analysis*. Tata McGraw Hill.
- Banks J. 1998. *Handbook of Simulation*. John Wiley.
- Brately P, Fox B.L. and Scharge LE. 1987. *A Guide to Simulation*. Springer.
- Deo N. 1987. *System Simulation with Digital Computer*. Prentice Hall of India.
- Gentle G.E. 2005. *Random Number Generation and Monte Carlo Methods*. Springer.
- Gordan G. 2007. *System Simulation*. Pearson Edu.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Press W.H., Flannery B.P., Tenkolsky S.A. and Vetterling W.T. 1986. *Numerical Recipes: The Art of Scientific Computing*. Cambridge Univ. Press.
- Ripley B.D. 1987. *Stochastic Simulation*. John Wiley.
- Taha H.A. 2003. *Operations Research: An Introduction*. Prentice Hall of India.

Course Title : Introduction to Big Data
Course Code : MCA 604
Credit Hours : 2+1

Aim of the course

This course provides exposure to different aspects of use of big data in agriculture and industrial research. It helps in providing information about the analysis procedure for Big data.

Theory

Unit I

Introduction to Big Data; Big Data Foundations, Components of big data infrastructure; Hadoop; Spark 2.0, installation, Hadoop Distributed File System, reading and processing Big data

Unit II

Introduction to MapReduce, Algorithms for common problems; NoSQL, Scripting

Unit III

Data visualization and mining big data

Unit IV

Processing streaming data, text and natural language processing

Suggested Reading

- Davenport T.H. 2016. *Big Data at Work: Dispelling the Myths, Uncovering the Opportunities.* Kindle Ed.
- Maheshwari A. 2018. *Data Analytics Made Accessible*. Kindle Ed.
- Simon P. 2018. *Too Big to Ignore: The Business Case for Big Data*, Wiley and SAS Business Series
- Schönberger V.M. and Cukier K. 2015. *Big Data: A Revolution That Will Transform How We Live, Work, and Think,*Kindle Ed.

I. Course Title : Introduction to Internet of Things
II. Course Code : MCA 605
III. Credit Hours : 2+1
IV. Aim of the course

This course provides exposure to different aspects of research, implementation, and business with IoT. It also deals withchallenges and techniques for building different IoT solutions. IoT-based applications such as innovative shopping system, infrastructure management in both urban and rural areas, remote health monitoring and emergency notification systems, and transportation systems.

V. Theory

Unit I

Introduction to IoT: Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications

Unit II

Interoperability in IoT, Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Introduction to Python programming, Introduction to Raspberry, Implementation of IoT with Raspberry.

Unit III

Introduction to SDN, SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor-Cloud.

Unit IV

Fog Computing, Smart Cities and Smart Homes, Connected Vehicles, Smart Grid, Industrial IoT.

VI. Practical

- Case Study: Agriculture, Healthcare, Activity Monitoring

VII. Suggested Reading

- Raj P. and Raman A.C. 2017. *The Internet of Things: Enabling Technologies, Platforms, and Use Cases*, CRC Press.
- Bahga A. and Madisetti V. 2017. *Internet of Things: A Hands-on Approach*, Universities Press.

I. Course Title : Management Information System

II. Course Code : MCA 606

III. Credit Hours : 2+0

IV. Aim of the course

This course provides exposure to challenges and techniques for management Information Systems. The course deals with theoretical aspects on how to manage the information systems.

V. Theory

Unit I

Information Systems in Global Business – Role of Information Systems in Business; Emergence of Digital Firms, Perspectives on Information Systems.

Unit II

Business Processes and Information Systems; how Information Systems improve Businesses; Types of Information Systems – Transaction Processing Systems; Management Information Systems; Decision Support Systems; Executive Information System.

Unit III

Organizations and Information Systems – Impact of Information System on organization –Economic, Organization and behavioral impacts; Competitive Advantages using Information Systems.

Unit IV

Enterprise wide Applications – ERP, CRM, Business Intelligence, Collaboration Tools and its use; E-Commerce; Social Media; Ethical Issues, privacy and regulations.

VI. Suggested Reading

- Amoroso E. 1994. *Fundamentals of Computer Security Technology*. Prentice-Hall.
- Bhushan M. 2017. *Fundamentals of Cyber Security* Prentice Hall.
- Chapman B & Zwicky ED. 2000. *Building Internet Firewalls*. O'Reilly.

I. Course Title : Computer Oriented Numerical Methods

II. Course Code : MCA 611

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on computer oriented numerical methods that aims at exposing the students to introduce numerical algorithms and to solve mathematical problems using numerical approximations

V. Theory

Unit I

Errors in computations: Basic concepts: Floating point number system, Implication of finite precision, Rounding off errors

Unit II

Finite Differences, Interpolation: Polynomial interpolation, Inverse interpolation, Spline interpolation; Numerical integration: Trapezoidal rule, Simpson's 1/3rd and 3/8th rules; Ordinary differential equations: Runge-Kutta methods, Predictor - correctormethods.

Unit III

Linear system of equations: Gaussian's elimination, Operation counts, Implementation including pivoting and scaling, Direct factorization methods, Iterative techniques and their analysis.

Unit IV

Linear Difference equations; Non-linear equations: Bisection, Newton Raphson, false positions, Secant methods, Iterative methods.

Unit V

Inverse of Matrices; Computation of Eigen values and Eigen vectors: Error estimates, the power methods – Jaccobi and Householder Method.

VI. Practical

- Solving polynomial and algebraic equations using numerical approximations, finding minimum and maximum of functions;
- Inversion of matrices, rank of a matrix,

- Choleskey Decompositions,
- Structural Value Decomposition and Eigen Values.

VII. Suggested Reading

- Atkinson K.E. and Han W. 2003. *Elementary Numerical Analysis*. 3rd Ed. John Wiley.
- Atkinson K.E. 1978. *An Introduction to Numerical Analysis*. John Wiley.
- Jain M.K., Iyengar S.R.K. and Jain R.K. 2007. *Numerical Methods for Scientific and* Engineering *Computation*. 7th Ed. New Age.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Krishnamurthi E.V. and Sen S.K. 1986. *Computer-Based Numerical Algorithms*. East West Publ.
- MacMillan. C. 2012. *Elementary Numerical Analysis An Algorithmic Approach:* John Wiley

I. Course Title : Artificial Intelligence and Machine Learning

II. Course Code : MCA 612

III. Credit Hours : 2+1

IV. Aim of the course

The primary objective of this course is to provide an introduction to the basic principles and applications of Artificial Intelligence that includes problem solving, knowledge representation, reasoning, decision making, planning, perception & action, and learning.

V. Theory

Unit I

Introduction to Artificial Intelligence (AI); Scope of AI: Games, theorem proving, natural language processing, robotics, expert system.

Unit II

Knowledge: General concept of knowledge, Knowledge based system, Representation of knowledge, Knowledge organization and manipulation, Acquisition of knowledge.

Unit III

Symbolic approach: Syntax and Semantics for Prepositional Logic (PL) and First order predicates logic (FOPL), Properties of well-formed formulas (wffs), Conversion to clausal form, Inference rules, Resolution principle, Non deductive inference methods.

Unit IV

Search and Control strategies: Blind search, Breadth- first search, Depth – First search, Hill climbing method, Best – First search, Branch and Bound search.

Unit V

Learning: Concept of learning, learning automation, genetic algorithms, learning by induction.

Unit VI

Expert System: Introduction to expert system, Characteristics features of expert system, Applications, Importance of Expert system, Rule based system architecture.

VI. Practical

- Search and Control strategies: Blind search, Breadth- first search, Depth – First search, Hill climbing method, Best – First search, Branch and Bound search;

- Learning by induction;
- Genetic algorithms;
- Case study of a rule based expert system and Construction of Decision tree.

VII. Suggested Reading

- Akerkar R. 2005. *Introduction to Artificial Intelligence*. Prentice-Hall of India.
- Giarratano J. and Riley G. 1998. *Expert Systems - Principles and Programming*. 3rd Ed. PWS Publ.
- Gonzalez A. and Dankel D. 2004. *The Engineering of Knowledge-Based Systems*. Prentice Hall.
- Hill E.F. 2003. *Jess in Action*. Manning Publ.
- Jackson P. 1999. *Introduction to Expert Systems*. Addison Wesley.
- Nilson N.J. 2014. *Artificial Intelligence: A New Synthesis*. Maurgan Kaufman.
- Nilson N.J. 2001. *Principles of Artificial Intelligence*. Narosa.
- Rich E. and Knight K. 2002. *Artificial Intelligence*. Tata McGraw Hill.
- Russell S. and Norvig P. 2003. *Artificial Intelligence: A Modern Approach*. Prentice Hall.

I. Course Title : Multimedia and Applications

II. Course Code : MCA 613

III. Credit Hours : 1+1

IV. Aim of the course

This course introduces students to current practices, technologies, methodologies, and authoring systems in the design and implementation of systems that incorporate text, audio, images, animation and full-motion video.

V. Theory

Unit I

Introduction to Multimedia Technology - Computers, communications and entertainment; Framework for multimedia systems.

Unit II

M/M devices, presentation devices and the user interface, M/M presentation and authoring.

Unit III

Digital representation of sound and transmission; Brief survey of speech recognition and generation; Digital video and image compression; JPEG image compression standard; MPEG motion video compression.

Unit IV

DVD technology, Time based media representation and delivery; M/M software environment; Limitation of workstation operating systems.

Unit V

M/M systems services; OS support for continuous media applications; Media stream protocol; M/M file system and information representation.

Unit VI

Data models for M/M and Hypermedia information.

VI. Practical

- Script Writing and Story Boards;

- Hot Spots and Buttons, Layouts and designing of visuals, Basics of colors;
- Working with text, presentations, charts and putting animations;
- Creating interactive presentations;
- Adobe Photoshop – Introduction, Working with images, Image editing and cleaning;
- Macromedia Flash - Introduction, Creating shapes, Inserting text, Concepts of colors, layers, frames and timelines;
- Creating Animation - Creating scenes, creating movie, testing and playing movie;
- Adobe Acrobat – Overview, Creating Adobe PDF e-Books;
- Macro Media Director Basics.

VII. Suggested Reading

- Furhet B. 1998. *Multimedia Technologies and Applications for the 21st Century*. Kluwer.
- Gibbs S.J. and Tsischritziz D.C. 1995. *Multimedia Programming - Objects, Environment & Framework*. Addison-Wesley.
- Kerman P. 2002. *Teach Yourself Macromedia Flash MX*. Sams Publ. Luther AC. 1994. *Authoring Interactive Multimedia*. Academic Press. Parekh R. 2006. *Principles of Multimedia*. TataMcGraw-Hill.
- Vaughan T. 2017. *Multimedia-Making it Work*.McGraw-Hill.

List of Journals

Agricultural Statistics

- *American Statistician*
- *Annals of Institute of Statistical Mathematics*
- *Annals of Statistics*
- *Australian and New Zealand Journal of Statistics*
- *Biometrical Journal*
- *Biometrics*
- *Biometrika*
- *Bulletin of Calcutta StatisticalAssociation*
- *Canadian Journal of Statistics*
- *Communication in Statistics (Simulation and Computation)*
- *Communication in Statistics (Theory and Methods)*
- *Experimental Agriculture*
- *Institute of Mathematical Statistics Bulletin (IMSB)*
- *Journal of American Statistical Association*
- *Journal of Applied Statistics*
- *Journal of the Indian Society of Agricultural Statistics*
- *Journal of the International Statistical Review*
- *Journal of Statistical Planning and Inference*
- *Journal of Statistical Theory andPractice*
- *Journal of Statistics, Computer and Applications*
- *Journal of Royal Statistical Society, Series A*
- *Journal of Royal Statistical Society, Series B*
- *Journal of Royal Statistical Society, Series C*
- *Metrika*
- *Metron*
- *Scandinavian Journal of Statistics (Theory & Applied)*
- *Sankhya*
- *Statistica*
- *Statistical Science*
- *Statistics and Probability Letters*
- *Technometrics*
- *Utilitas Mathematica*

Computer Application

- *ACM Transactions on Knowledge Discovery from Data*
- *Applied Intelligence–The International Journal of Artificial Intelligence, Neural Networks, and Complex Problem-Solving Technologies*
- *Computational Statistics and Data Analysis, Elsevier Inc.*
- *Computers and Electronics in Agriculture, Elsevier Inc.*
- *Data Mining and Knowledge Discovery: An International Journal (DMKD)*
- *Expert Systems with Applications, Elsevier Inc.*
- *IEEE Transactions on Knowledge and Data Engineering*
- *IEEE Transactions on Neural Networks*
- *IEEE Transactions on Pattern Analysis and Machine Intelligence*
- *International Journal of Computing and Information Sciences*
- *International Journal of Information and Management Sciences*
- *International Journal of Information Technology*
- *Journal of Artificial Intelligence Research*
- *Journal of Combinatorics, Information and System Sciences*
- *Journal of Computer Sciences and Technology*
- *Journal of Computer Society of India*
- *Journal of Indian Society of Agricultural Statistics*
- *Journal of Intelligent Information Systems - Integrating Artificial Intelligence and Database Technologies*
- *Journal of Machine Learning Research*
- *Journal of Statistics, Computer and Applications*
- *Journal of Systems and Software*
- *Journal of Theoretical and Applied Information Technology*
- *Knowledge and Information Systems: An International Journal (KAIS)*
- *Lecture Notes in Computer Science, Springer Verlag.*
- *Machine Learning*
- *Transactions on Rough Set*

e-Resources

- Design Resources Server. *Indian Agricultural Statistics Research Institute (ICAR), New Delhi 110 012, India*.www.drs.icar.gov.in.
- Free Encyclopedia on Design of Experiments
- http: //en.wikipedia.org/wiki/Design_of_experiments
- Statistics Glossaryhttp: //www.cas.lancs.ac.uk/glossary_v1.1/main.html.
- Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html.
- Hadamard Matriceshttp: //www.research.att.com/~njas/hadamard;
- Hadamard Matrices http: //www.uow.edu.au/~jennie/WILLIAMSON/williamson.html.
- Course on Experimental design: http://www.stat.sc.edu/~grego/courses/stat706/.
- Learning Statistics: http: //freestatistics.altervista.org/en/learning.php.
- Free Statistical Softwares: http://freestatistics.altervista.org/en/stat.php.
- Statistics Glossaryhttp: //www.cas.lancs.ac.uk/glossary_v1.1/main.html.
- Statistical Calculators: http: //www.graphpad.com/quickcalcs/index.cfm
- SAS Online Doc 9.1.3: http: //support.sas.com/onlinedoc/913/docMainpage.jsp

Suggested Broad Topics for Research Agricultural Statistics

- Design and analysis of multi-response experiments
- Design and analysis of micro-array experiments
- Design and analysis of experiments for precision agriculture
- Design and analysis of agroforestry experiments
- Designs for computer experiments.
- Bayesian designing of experiments, Bayesian optimality and Bayesian analysis of experimental data

- Computer aided search of efficient experimental designs for various experimental settings
- Fractional factorials including search designs, supersaturated designs, computer experiments, etc.
- Statistical techniques in bioinformatics, biotechnology, microbiology, genomics, etc.
- Optimality aspects and robustness of designs against several disturbances under various experimental settings (single factor, multi-factor, nested classifications, etc.)
- Small area estimation
- Computer intensive techniques in sample surveys
- Analysis of survey data, regression analysis, categorical data analysis, analysis of complex survey data
- Assessment and impact survey methodologies, valuation of natural resources, its degradation, depletion, etc.
- Linear and non-linear modeling of biological and economical phenomena
- Non-linear time series modeling
- Non-linear stochastic modeling
- Forecast models for both temporal and spatial data
- Innovative applications of resampling techniques
- Applications of remote sensing, GIS, ANN, etc. in modeling various phenomena
- Econometric models for risk, uncertainty, insurance, market analysis, technical efficiency, policy planning, etc.
- Statistical studies on value addition to crop produce

Computer Application

- Web solutions inagriculture
- Decision Support/ Expert Systems/ Information Management Systems in Agriculture
- Software for Statistical DataAnalysis
- Modelling and Simulation of Agricultural Systems
- Application Software for GIS and Remote Sensing
- Office Automation and Management System

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ISBN:978-81-7164-236-6