

VOL.
1



Agriculture and Allied Sciences

Restructured and Revised Syllabi of Post-graduate Programmes

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



Education Division

Indian Council of Agricultural Research
New Delhi

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Volume-1

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त्रिलोचन महापात्र, पीएच.डी.

एफ एन ए, एफ एन ए एस सी, एफ एन ए ए एस

सचिव एवं महानिदेशक

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SECRETARY & DIRECTOR GENERAL

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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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Common Academic Regulations for PG and Ph.D. Programmes

1. Academic Year and Registration
2. Credit requirements
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 - 2.2 Supporting courses
 - 2.3 Syllabus of Common Courses for PG programmes
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6. Evaluation of research work
 - 6.1 Prevention of plagiarism
7. Learning through online courses
8. Internship during Masters programme
9. Teaching assistantship
10. Registration of project personnel (SRF/ RA) for Ph.D.
11. Compliance with the National Education Policy-2020
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 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 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 vascupets;
- 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 latest developments 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 4th and 6th semester of his/ her residency 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 examination should be based on oral examination by 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 desirable for Ph.D. programme and this should be done annually as an essential part of research evaluation. The Student Advisory Committee shall review 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 enhanced partnerships 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 and 10 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 of the 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 hours of 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

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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 (<i>Kharif</i> Crops)	3 (2+1)
GPB 512	Crop Breeding-II (<i>Rabi</i> 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	20
	(minimum 20 credits from above courses including *marked Courses)	
	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 Benjamin/ 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 inbreds, breeding approaches for improvement of inbreds, predicting hybrid performance; seed production of hybrid and their parent varieties/ inbreds. 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, $L \times T$, NCDs, and TTC; Concept of combining ability and gene action, $G \times E$ 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;
- $L \times T$ analysis and interpretation, QTL analysis;
- Use of computer packages;
- Diallel analysis;
- $G \times E$ 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 systems and 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, pearl millet, sorghum, maize and ragi, etc.); Pulses (green gram, black gram, cowpea, pigeon pea, chickpea, field pea, 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*. IRL Press, Oxford.
- Gupta PK and Tsuchiya T. 1991. *Chromosome Engineering in Plants: Genetics, Breeding and Evolution*. Part A.
- Gupta PK. 2010. *Cytogenetics*. Rastogi Publishers.
- Johansson 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_2 s, 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, Expaty 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. *Speciality Rices 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 Energy Agency, Vienna, Italy.
- Shu QY, Forster BP and Nakagawa N. 2012. *Plant Mutation Breeding and Biotechnology*. Gutesnberg 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 varieties and 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 inbreds, 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 inbreds 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 Convventional 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, released varieties, 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. 1986. *Rice Genetics*. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.
- IRRI. 1991. *Rice Genetics II*. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.
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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.
- Kaloo G. 1988. *Vegetable Breeding*. Vols. I-III. CRC Press.
- Kaloo 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 and region 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*, *Bougainvillea*, 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 F₁ 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, Boserak 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. Hazeckamp 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.
- Sundeeep 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 using 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, floescence 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 various plant 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_{α} 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 $G \times E$ 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

$G \times E$ 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 Data*. 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 of this 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; Homeostasis- 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, Intergenic 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 C₃ to C₄ 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 nutraceutical value.

X. Suggested Reading

Balint A. 1984. *Physiological Genetics of Agricultural Crops*. AK Ademiaikiado.

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

Pessaraki 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 competitiveness 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; polyembryony – 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.



Kozłowski, T.T. 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 significance.

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.
- Kozłowski 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

- <https://www.springer.com/in/book/9780792373223>
- <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=91nsCAAQBAJ&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

- <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.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_enhancement_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 solanaceous, 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. Malhotra 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.

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

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

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

<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](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/amprs.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.
- Gutteridge 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](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.
- Chakrabarathi 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=SQWHAACAAJ&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, Sathiyarayanan 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 ProcessingandStorageVer_1pt3.pdf](https://www.carolinafarmstewards.org/wpcontent/uploads/2012/05/Seed_ProcessingandStorageVer_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.



- Chakrabarthy 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](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.seedtest.org/upload/cms/user/ISTAMethodValidationforSeedTesting-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/FCBU054.pdf/$FILE/FCBU054.pdf)
- [https://www.forestry.gov.uk/PDF/FCBU059.pdf/\\$FILE/FCBU059.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=vPV1Bos4WkYC>
<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., Minneapolis, 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=lvVJAAAYAAJ&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, pearl millet, 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, pearl millet, sunflower and red gram; brinjal and chillies;
- Practicing planting design and border rows in tomato, cotton and cucurbitaceous vegetables;
- Manipulation for synchronization – rice, sunflower, pearl millet and sorghum;
- Practicing supplementary pollination – rice and sunflower;
- Practicing field inspection in hybrid seed production plot – crops planted in ratio – sunflower, pearl millet, 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-andpractices/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://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/apedaweb/organic/organic.../english_organic_sept05.pdf
- 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 its survival.

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 Heidelberg, 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://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/physiologyofseedfrontmatter>

**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](http://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.
- Chakrabarthy 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/tgdocs/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.
- Chakrabarthy 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_Principiland_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/60047727>
- http://wrap.warwick.ac.uk/74767/1/WRAP_0380014-1f-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/a5af7beae17bd31058db0f645edd647cbb9e9c2b>

- 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.
- Kozłowski 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-0851996531/57DACB0A07CFD0246AAD11713540F1E6>



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-Agriculture/Benech-Arnold-Sanchez/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=hp_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 Iarinde 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%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 adoption 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_forest_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://www.biologie.uni-regensburg.de/seed%20ecology)
- <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-9780199830060-0086.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 policies – 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*.
- Dadhech 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-launching-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=vPVIbos4WkYC>
- <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 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 competitiveness. 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, Intraspecific 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 agrobiodiversity-*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.
- Bonner FT. 1990. 'Storage of seeds: Potential and limitation of germplasm conservation.' *Forest Ecology and Management*.
- Chaudhury R and Malik SK. 2017. *Cryopreservation of Plant Species: Practical Approaches from Handling to Cryobanking*. ICAR-NBPGR, New Delhi. 52 p.
- Dodds JH. (eds.) 1991. *In vitro Methods for Conservation of Plant Genetic Resources*. Chapman and Hall, London.
- 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.
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- Ford-Lloyd BV, Newbury JH and Callow JA. (eds.) 1998. *Biotechnology and Plant Genetic Resources: Conservation and Use*. CABI, Wallingford.
- 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 Raton, 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.
- Sundeeep 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 using 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, fluorescence 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's encyclopedia 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, Brahma, P.Mathur, PN and Bansal, KC). Bioersity 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 on safe exchange of germplasm nationally and internationally along with 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 biosecure india 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, Backcross), 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 disassortive 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	<i>In-situ on farm</i> 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-vitrification, 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 Michael E. S. 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 Ethnopharmacology 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-ipmttguide.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's G_{st}, 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 patterns- 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

- Ananthakrishnan. 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, Hettterscheid 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, Loipez 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. Bioersivity 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 bhaha4@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 shivratn.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
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Vol. 1

Plant Protection

- Entomology
- Plant Pathology
- Nematology

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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 stakeholders 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 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 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); organogenesis 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.
- Snodgrass RE. 1993. *Principles of Insect Morphology*. Cornell Univ. Press, Ithaca.
- Tembhore DB. 2000. *Modern Entomology*, Himalaya Publishing House, Mumbai.
- Steher 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, biosynthesis 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 systematics, 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 Panorpid 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. *Borrer 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*. Narosa 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 Shadara 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 their Management*. 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*. Asiatic 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, New York.
- 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 Behaviour*. 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.
- Graham 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 Agricultural 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 production 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, α -amylase inhibitors, lectins, terpenes 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 release of insects carrying a dominant lethal gene. Methods and application of insect transgenesis, 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 spectrophotometric 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.
- Hagedorn 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 a good 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 procedures. 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 (Ceratopogonidae).

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 acarids: 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 affecting 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.
- Stebbing 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: Kukulova 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 systematics.

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 cuticle.

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, neurotransmitters 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*. Harvard University Press, Harvard.
- 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, Orthogalumnaeidae, 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 reproductory 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, Loculoascomycetes 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 symptomatic 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, Clustal 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; Lipopolysaccharide structure; Membrane transport; fimbriae 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.
- Mathews REF. 1993. *Diagnosis of Plant Virus Diseases*. CRC Press, Florida.
- Noordam D. 1973. *Identification of Plant Viruses, Methods and Experiments*. Cent. Agric. 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-infectious 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, nematocides, 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 nematocides;
- *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, their compatibility 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 International 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 solanaceous vegetables. Diseases of crops under protected cultivation.

Unit II

Symptoms and management of diseases of different root, tuber, bulb, leafy vegetables, crucifers, cucurbits and solanaceous 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 Alimentarius 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, arthrospores;
- Study of fruiting bodies in Ascomycotina;
- Identification of fungi up to species level;
- Study of hyphal anastomosis;
- Morphology of representative plant pathogenic genera from 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 origin 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-Parnas (EMP) pathway, Phosphoketolase Pathway and Entner Doudoroff Pathway).

Unit II

Current trends in taxonomy and identification of phytopathogenic prokaryotes: 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.shtm>
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.



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- *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*. 2nd 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, mycophagous 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-Loipez, RH and Marbain-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 antinematic 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, Ehlers 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.
- Metcalfe 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 infectious 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 disinfection/ 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 Brasileira* – 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 nematotoxicity
- 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

- Andraïssy 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*. E.J. 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 with 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; nematotoxic 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.shtm>
- 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 Nematology Morphology and Systematics* – Jaen, Universidad de Jaen
- *Nematologia Brasileira* – Brazilian Nematological Society
- *Nematologia Mediterranea* – Istituto per la Protezione delle Plante (IPP) – Sect. of Bari of the CNR, Italy
- *Nematology* – E.J. 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 nematotoxicity
- 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, 'Vrudhhi' 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
Syllabi of Post-graduate Programmes
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)

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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.

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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 export 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 many 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
- 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.
 - 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-Horticultural Sciences 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: Principles and 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 Whaley 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
2	Agro-Techniques
3	Crop Management

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.
- Ladanya 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 Nut Varieties*. 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*. 2nd Edn. Elsevier.
- Spencer RR, Cross R and Lumley P. 2003. *Plant Names*. 3rd Ed. *A Guide to Botanical Nomenclature*, CISRO, Australia.
- Srivastava U, Mahajan RK, Gangopadhyay 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, brassinosteroids, 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, Gruissem 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 Wiley & 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	<i>In-vitro</i> Culture and Hardening
3	Genetic Manipulation	<i>In-vitro</i> 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*. Springer.
- 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 – CO₂ 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*. Springer-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 impart 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 technologies.

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 Sanyal 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, Gruissem 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 update 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 CO₂, 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 fluorescence, 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 Intellectual Property Rights	Germplasm Exchange, Quarantine and



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 Horticultural Crops*. 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.	<i>Advances in Horticultural Science</i>	0394-6169
2.	<i>Acta Horticulturae</i>	0567-7572
3.	<i>American Journal of Enology and Viticulture</i>	0002-9254
4.	<i>Annals of Arid Zone</i>	0570-1791
5.	<i>Annals of Horticulture</i>	0974-8784
6.	<i>Biodiversity and Conservation</i>	0960-3115
7.	<i>Current Horticulture</i>	2347-7377
8.	<i>European Journal of Horticultural Science (Gartenbauwissenschaft)</i>	1611-4426
9.	<i>Fruits</i>	0248-1294
10.	<i>Genetic Resources and Crop Evolution</i>	0925-9864
11.	<i>Horticultural Plant Journal</i>	2488-0141
12.	<i>Horticulture Environment and Biotechnology</i>	2211-3452
13.	<i>HortScience</i>	0018-5345
14.	<i>Indian Horticulture Journal</i>	2249-6823
15.	<i>Indian Journal of Arid Horticulture</i>	Naas-1234
16.	<i>Indian Journal of Dryland Agricultural Research and Development</i>	0971-2062



Sr. No.	Name of the Journal	ISSN No.
17.	<i>Indian Journal of Horticulture</i>	0972-8538
18.	<i>International Journal of Fruit Science</i>	1553-8621
19.	<i>International Journal of Horticulture</i>	1927-5803
20.	<i>International Journal of Innovative Horticulture</i>	2320-0286
21.	<i>Journal of Applied Horticulture</i>	0972-1045
22.	<i>Journal of Horticultural Research</i>	2300-5009
23.	<i>Journal of Horticultural Science and Biotechnology</i> <i>(Journal of Horticultural Science, England)</i>	1462-0316
24.	<i>Journal of Horticultural Sciences</i>	0973-354X
25.	<i>Journal of Horticulture</i>	2376-0354
26.	<i>Journal of The American Society for Horticultural Science</i>	0003-1062
27.	<i>Journal of Tree Fruit Production</i>	1055-1387
28.	<i>New Zealand Journal of Crop and Horticultural Science</i>	0114-0671
29.	<i>Progressive Horticulture</i>	0970-3020
30.	<i>Scientia Horticulturae</i>	0304-4238
31.	<i>The Asian Journal of Horticulture</i>	0973-4767
32.	<i>The Journal of American Pomological Society</i>	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, nutraceutically rich, economically viable and generating substantial on-farm and off-farm employment. Vegetables have a preeminent place in Indian agricultural economy. The country is being blessed with diverse agro-climatic conditions ranging from the temperate 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 consciousness, 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 advances made in the vegetable production by revisiting 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 traits in Vegetable crops, Biodiversity and conservation of Vegetable crops, Biotechnological approaches in Vegetable crops and Advanced laboratory 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, hydroponics 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.
- Hazra P. 2016. *Vegetable Science*. 2nd edn, Kalyani publishers, Ludhiana.
- Hazra P. 2019. *Vegetable production and technology*. New India publishing agency, New Delhi.
- Hazra P, Chattopadhyay A, Karmakar K and Dutta S. 2011. *Modern technology for vegetable production*, New India publishing agency, New Delhi, 413p
- Rana MK. 2008. *Olericulture in India*. Kalyani publishers, New Delhi.
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- 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.
- Shanmugavelu KG. 1989. *Production technology of vegetable crops*. Oxford and IBH.
- Singh DK. 2007. *Modern vegetable varieties and production technology*. International book distributing 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 : 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

- 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 Kallou G. (Eds.). 1993-94. *Advances in horticulture* Vols. V-X. Malhotra publ. house.
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- Hazra P. 2016. *Vegetable science*. 2ndedn, Kalyani publishers, Ludhiana.
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- Hazra P, Chattopadhyay A, Karmakar K and Dutta S. 2011. *Modern technology for vegetable production*, New India publishing agency, New Delhi, 413p
- 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.
- Shanmugavelu KG., 1989. *Production technology of vegetable crops*. Oxford and IBH.
- Singh DK. 2007. *Modern vegetable varieties and production technology*. International book distributing 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 : 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	<ol style="list-style-type: none">1. Introduction and phytohormones2. Physiology of dormancy and germination3. Abiotic factors4. Fruit physiology5. 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, gibberellins, cytokinins 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.
- Kaloo 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.
- Leopold AC and Kriedemann PE. 1981. *Plant growth and development*, Tata McGraw-Hill, New Delhi.
- 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. (Eds). 2008. *Basics of horticulture*. New India publication agency, New Delhi.
- Rana MK. 2011. *Physio-biochemistry and Biotechnology of Vegetables*. New India Publishing Agency, Pritam Pura, New Delhi.
- 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.
- Kaloo 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.
- Peter KV and Pradeep Kumar T. 1998. *Genetics and breeding of vegetables*. ICAR, New Delhi, p. 488.
- 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.
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- Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.
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- Hazra P and Som MG. 2015. *Vegetable science (Second revised edition)*, Kalyani publishers, Ludhiana, 598 p.
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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 : 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.
- 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
- Kaloo G. 1988. *Vegetable breeding*. Vols. I-III. CRC Press.
- Kaloo 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.
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- Prohens J and Nuez F. 2007. *Handbook of Plant Breeding- Vegetables* (Vol I and II), Springer, USA.
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- Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi.
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- 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 : 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.
- Kaloo G and Singh K. (Eds.). 2000. *Emerging scenario in vegetable research and development*. Research periodicals and Book publ. house.
- 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*. 7th Edn. 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.



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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

- Agarwal 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.
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- 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.
- Kaloo G, Jain SK, Vari AK and Srivastava U. 2006. *Seed: A global perspective*. Associated publishing company, New Delhi.
- Hazra P and Som HG. 2015. *Seed production and hybrid technology of vegetable crops*. Kalyani publishers, Ludhiana.
- 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.
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- Soule J. 1985. *Glossary for Horticultural Crops*. John Wiley and Sons.
- Srivastava U, Mahajan RK, Gangopadhyay 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, Panchyagavya, 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 as an 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.
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- 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
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- 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.
- Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Postharvest biology and technology of Fruits, vegetables and flowers*. Wiley-Blackwell, ISBN: 9780813804088.
- Ranganna S. 1997. *Handbook of analysis and quality control for fruit and vegetable products*. Tata McGraw-Hill.
- Stawley JK. 1998. *Postharvest physiology of perishable plant products*. CBS publishers.
- Sudheer KP and Indira V. 2007. *Postharvest technology of horticultural crops*. New India Publ. Agency.



- Thompson AK. (Ed.). 2014. *Fruit and vegetables: harvesting, handling and storage* (Vol. 1 and 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.
- 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	<ol style="list-style-type: none">1. Solanaceous crops2. Cole crops3. Okra, onion, peas and beans, amaranth and drumstick.4. Root crops and cucurbits5. 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.
- Gopalakrishanan TR. 2007. *Vegetable crops*. New India Publ. Agency.
- Hazra P and Som MG. 2015. *Seed production and hybrid technology of vegetable crops*. Kalyani publishers, Ludhiana.
- Hazra P. 2016. *Vegetable science*. 2ndedn, Kalyani publishers, Ludhiana.
- Hazra P. 2019. *Vegetable production and technology*. New India publishing agency, New Delhi.
- Kaloo 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.
- Shanmugavelu KG. 1989. *Production technology of vegetable crops*. Oxford and IBH.
- 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 Advances 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
- Kaloo G. 1988. *Vegetable breeding* (Vol. I, II, III). CRC Press, FL, USA.
- Kaloo 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 Kaloo 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.
- 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.
- 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 be 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 play a vital role in agriculture and act 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 exceeds 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
- Kaloo 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.

Hazra P and Som MG. 2015. *Vegetable science* (Second revised edition), Kalyani publishers, Ludhiana, 598p.



- Hazra P and Som MG. 2016. *Vegetable seed production and hybrid technology* (Second revised edition), Kalyani Publishers, Ludhiana, 459p
- Kaloo G. 1988. *Vegetable breeding*. Vols. I-III. CRC Press.
- Kaloo 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 Kaloo 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
- 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.
- 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.
- Rout GR and Peter KV. 2008. *Genetic engineering of horticultural crops*. Academic press, Elsevier, USA
- 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, 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;
- 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.
- Peter KV. 2011. *Biodiversity in horticultural crops*. Vol.III. Daya Publ. House, Delhi.
- Rajasekharan PE, Rao V and Ramanatha V. 2019. *Conservation and utilization of horticultural genetic resources*. Springer.
- Rana JC and Verma VD. 2011. *Genetic resources of temperate minor fruits (indigenous and exotic)*. NBPGR, New Delhi.
- 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. Biosafety 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.
- Panopoulos 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 Elsevier, 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.	<i>American Journal of Horticultural Sciences</i>	0003-1062
2.	<i>American Potato Growers</i>	
3.	<i>American Scientist</i>	1545-2786
4.	<i>Annals of Agricultural Research</i>	9703179
5.	<i>Annual Review of Plant Physiology</i>	0066-4294
6.	<i>California Agriculture</i>	1097-0967
7.	<i>Haryana Journal of Horticultural Sciences</i>	0970-2873
8.	<i>HAU Journal of Research</i>	0379-4008
9.	<i>Horticulture Research</i>	2052-7276
10.	<i>HortScience</i>	2327-9834
11.	<i>IIVR Bulletins</i>	1462-0316
12.	<i>Indian Horticulture</i>	0019-4875
13.	<i>Indian Journal of Agricultural Sciences</i>	0019-5022
14.	<i>Indian Journal of Horticulture</i>	0974-0112
15.	<i>Indian Journal of Plant Physiology</i>	2662-2548
16.	<i>Journal of American Society for Horticultural Sciences</i>	0003-1062
17.	<i>Journal of Arecanut and Spice Crops</i>	
18.	<i>Journal of Food Science and Technology</i>	0975-8402
19.	<i>Journal of Plant Physiology</i>	0176-1617
20.	<i>Journal of Biology and Technology</i>	0925-5214
21.	<i>Postharvest Biology and Technology</i>	0925-5214
22.	<i>Scientia Horticulturae</i>	0304-4238
23.	<i>Seed Research</i>	2151-6146
24.	<i>Seed Science</i>	23171537
25.	<i>South Indian Horticulture</i>	0038-3473
26.	<i>Vegetable Grower</i>	2330-2321
27.	<i>Vegetable Science</i>	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 Interiorscaping, 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 Interiorscaping, 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, Aracaceae, Liliaceae, 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, Liliaceae.



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, liliium, 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, liliium, 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
2	Post harvest management and marketing	III. Crop Management IV. Flower regulation 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, liliun, 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: Soil 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 shrubby 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 Micropropagation
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. *Turfgrass Management*. Published by NAU, Navsari.
 Emmons R. 2007. *Turfgrass 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 CO₂; 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 phytosanitary 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, Gruissem 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.
- Leopold 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, Gruissem 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 <i>in-vitro</i> 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: Somaclonal 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	<i>In-vitro</i> techniques and biosynthetic pathways	I <i>In-vitro</i> 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, liliun, 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.

Panopoulos 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 CO₂ 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
2	Precision floriculture and regulations	IV Advances in flower crops 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, liliun, 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, liliun, 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 rubber 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
3	Harvest and Post harvest management	II Propagation and nursery management III Agro techniques 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.
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- 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.
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- 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 genus Elettaria*. 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 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.



- 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.
- Hota D. 2007. *Bio Active Medicinal Plants*. Gene Tech Books. Jain SK. 2000. *Medicinal Plants*. National Book Trust.
- Khan IA and Khanum A. 2001. *Role of Biotechnology in Medicinal and Aromatic Plants*. Vol. IX. Vikaaz Publ.
- Kurian A and Asha Sankar M. 2007. *Medicinal Plants*. Horticulture Science Series, New India Publ. Agency.
- 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.
- Anonymous. 1985. *Rubber and its Cultivation*. The Rubber Board of India.
- Chadha KL, Ravindran PN and Sahijram L. 2000. *Biotechnology in Horticultural and Plantation Crops*. Malhotra Publ. House.
- Chadha KL. 1998. *Advances in Horticulture*. Vol. IX,X. *Plantation and Spices Crops*. Malhotra Publishing House, New Delhi.
- Chadha KL and Rethinam P. Eds. 1993. *Advances in Horticulture*. Vol. IX. *Plantation Crops and Spices*. Part-I. Malhotra Publ. House.
- Chopra VL and Peter KV. 2002. *Handbook of Industrial Crops*. Haworth Press, USA and Panama International Publ. (Indian Ed.).
- Choudappa P, Anitha K, Rajesh MK and Ramesh SV. 2017. *Biotechnology of Plantation Crops*. Daya Publishing House, New Delhi.
- Damodaran V K, Vilaschandran T and Valsalakumari PK. 1979. *Research on Cashew in India*. KAU, Trichur.
- 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.
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- Nybe EV, MiniRaj N and Peter KV. 2007. *Spices*. New India Publishing Agency.
- 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
- Ponnuswami et al. 2018. *Spices*. Narendra Publishing House, New Delhi.
- Raj PS and Vidyachandra B. 1981. *Review of Work Done on Cashew*. UAS Research Series No.6, Bangalore.
- Ramachandra et al. 2018. *Breeding of Spices and Plantation Crops*. Narendra Publishing House, New Delhi
- Ravindran PN. 2002. *Cardamom, the genus Elettaria*. 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, 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., *Rauwolfia 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 genus Elettaria*. 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.
- 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
- Prajapati ND, Purohit SS, Sharma AK, Kumar T. 2006. *A Hand book of Medicinal Plants*. Agro Bios (India).
- Ponnuswami *et al.* 2018. *Blossom biology of Horticultural crops*. Narendra Publishing House, New Delhi.
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- Sharma G. 2009. *Systematics of fruit Crops*. New India Publishing House, India.
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- 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. malabatum*, *Xanthoxylum* sp., *Curcuma caesia*, *C. aromatica*, *C. zedoaria*, *C. amada*, *Anethum graveolense*, *Hyssopus officinalis*, *Eringium foetidum*, *Pimpinella anisum*, *Artocarpus lacucha*.

C. Medicinal plants: *Flacourtia montana*, *Plectranthus aromaticus*, *Adhatoda* sp. *Hemidesmus indicus*, *Tinospora cordifolia*, *Gymnema sylvestre*, *Psoralea corylifolia*, *Eclipta alba*, *Aristolochia 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 start underutilized 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 Aromatic Plants*. Malhotra Publ. House.
- CSIR, *The Wealth of India*. Volume A-Z CSIR
- Farooqui AA, Khan MM and Sreeramu BS. 1997. *Cultivation of Medicinal and Aromatic Crops in India*. Naya Prokash.
- Jain SK. 1979. *Medicinal Plants*. National Book Trust.
- Kurian A and Asha Sankar M. 2007. *Medicinal Plants*. Horticulture Science Series, New India Publ. Agency.
- Nybe EV, Mini Raj N and Peter KV. 2007. *Spices*. Horticulture Science Series, New India Publ. Agency.
- Peter KV. *Under exploited and underutilized Horticulture crops*. Volume I-IV. New India Publication 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
- 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 PSMA.

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. Gruieessam 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
- Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*. Wiley.
- Fosket DE. 1994. *Plant Growth and Development: A Molecular approach*. Academic Press.
- Leopold AC and Kriedermann PE. 1985. *Plant Growth and Development*. 3rd Ed. McGraw-Hill
- 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
- Ravindran PN. 2000. *Black pepper, Piper nigrum*. CRC press
- Ravindran PN. 2002. *Cardamom, the genus Elettaria*. 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
- Roberts JS Downs and P Parker. 2002. *Plant Growth Development*. In: *Plants* (L. Ridge, Ed.), pp. 221-274, Oxford University Press
- Salisbury 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 PSMA. 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 PSMA.

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 PSMA-S 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.
- Daniel M and Mammen D. 2016. *Analytical methods for medicinal plants and economic botany*. Scientific publishers.
- Das K. 2013. *Essential oils and their applications*. New India Publishing Agency, New Delhi.
- E-manual on Advances in Cashew Production Technology*. ICAR -Directorate of Cashew Research, Puttur -574 202, DK, Karnataka.
- Hammon JM and Yusibov V. 2000. *Plant Biotechnology: New Products and application*. Springer-Verlag.
- Orhan I. 2012. *Biotechnological Production of Plant Secondary Metabolites*. Bentham Science Publishers.
- 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.
- Parimelzhagan T. 2013. *Turning plants into medicines: Novel approaches*. New India Publishing Agency, New Delhi.
- Pillay PNR. 1980. *Handbook of Natural Rubber Production in India*. Rubber Research Institute, Kottayam. pp.668.



- Ponnuswami *et al.* 2018 *Medicinal Herbs and herbal cure*. Narendra Publishing House, New Delhi.
- Raaman N. 2006. *Phytochemical techniques*. New India Publishing Agency, New Delhi.
- Raju R Wadekar. 2015. *Pharmacognosy and phytochemistry*, Event publishing house.
- Ramawat KG. 2007. *Biotechnology: secondary metabolites: plants and microbes*. Science Publishers.
- Ranjal Kandall. *Bioactive compounds and genomic study of medicinal plants*. LAMBERT Academic Publishing.
- 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.
- Shah B and Seth AK. 2005. *Text book of Pharmacognosy and Phytochemistry*. Cbs Publishers and distributors, New Delhi.
- Shankar SJ. 2018. *Comprehensive post harvest technology of flowers, medicinal and aromatic plants*. Narendra Publishing House, New Delhi
- Shukla YM. 2009. *Plant secondary metabolites*. New India Publishing Agency, New Delhi
- Syed Aftab Iqbal and Noor Ahmed Khan. 1993. *Text book of Phytochemistry*. Discovery Publishing house Pvt. Ltd.
- 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.
- E- manual on Advances in Cashew Production Technology*. ICAR -Directorate of Cashew Research, Puttur –574 202, DK, Karnataka
- Kassahun Beemnet, Jemal Omar Sherif, TessemaT'sion, Abate Solomon. 2009. *Production, Processing and utilization of Aromatic Plants*. EIAR.
- Khan JB and Singh GP. 2012. *Biodiversity Management and Conservation* LAMBERT
- Negi SS. *Biodiversity of India and its Conservation*.
- 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
- 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.
- Panda H. 2017. *Herbal and Aromatic Plants Cultivation, Processing, Utilisation and Applications*. Discovery publishing house, New Delhi
- Pillay PNR. 1980. *Handbook of Natural Rubber Production in India*. Rubber Research Institute, Kottayam. pp.668



- Ponnuswami *et al.* 2018. Medicinal Herbs and herbal cure. Narendra Publishing House, New Delhi
- Ponnuswami *et al.* 2018. Spices. Narendra Publishing House, New Delhi
- Pullaiah T. 2011. *Biodiversity in India* Vol.5. Daya Publishing house
- 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.
- Anonymous. 1985. *Rubber and its Cultivation*. The Rubber Board of India.
- Barche S. 2016. *Production Technology o Spices, Aromatic, Medicinal and Plantation Crops*. New India Publishing Agency, New Delhi.
- Chadha KL. 2001. *Hand Book of Horticulture*. ICAR.
- 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, D.K., 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.
- 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.
- Nybe EV, Mini Raj N and Peter KV. 2007. *Spices*. New India Publ. Agency.
- 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. 2001. *Hand Book of Herbs and Spices*. Vols. I-III. Woodhead Publ. Co., UK and CRC, USA.
- Peter KV. 2002. *Plantation Crops*. National Book Trust.
- Pillay PNR. 1980. *Handbook of Natural Rubber Production in India*. Rubber Research Institute, Kottayam. pp.668.
- Ponnuwami *et al.* 2018. *Spices*. Narendra Publishing House, New Delhi
- 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.
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- Ravindran PN. 2007. *Turmeric, the genus curcuma*. CRC press, Medicinal and Aromatic Plants – Industrial Profiles. Routledge, UK.
- Ravindran PN. 2001. *Monograph on Black Pepper*. CRC Press.
- Ravindran PN. 2017. *The Encyclopedia of Herbs and Spices*. CABI
- Ravindran PN and Madhusoodanan KJ. 2002. *Cardamom, the Genus Elettaria*. CRC press.
- Sera T, Socol 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.
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- 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	<ol style="list-style-type: none"> 1. Biodiversity of medicinal and aromatic crops 2. Area, production, productivity statistics 3. Export potential
2	Advanced Agro techniques	<ol style="list-style-type: none"> 1. Domestication studies 2. Varietal wealth and planting material production 3. Agro techniques 4. Impact of climate change
3	Harvest and post Harvest Management	<ol style="list-style-type: none"> 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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- Khan IA and Khanum A. 2001. *Role of Biotechnology in Medicinal and Aromatic Plants*. Vol. IX. Vikaaz Publ.
- Panda H. 2002. *Medicinal Plants Cultivation and their Uses*. Asia Pacific Business Press.
- 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.
- 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.
- 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-variety 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 inter-variety 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.

Anonymous. 1985. *Rubber and its Cultivation*. The Rubber Board of India.



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- Chadha KL. 2001. *Hand Book of Horticulture*. ICAR.
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- Chopra VL and Peter KV. 2005. *Handbook of Industrial Crops*. Panima.
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- Harler CR. 1963. *The Culture and Marketing of Tea*. Oxford Univ. Press.
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- Kurian A and Peter KV. 2007. *Commercial Crops Technology*. New India Publ. Agency.
- 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.
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- Peter KV. 2002. *Plantation Crops*. National Book Trust.
- Pillay PNR. 1980. *Handbook of natural rubber production in India*. Rubber Research Institute, Kottayam, 668pp.
- PonnuSwami et al. 2018. *Botany of Horticultural crops*. Narendra Publishing House, New Delhi.
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- PonnuSwami V et al. 2018. *Blossom biology of Horticultural crops*. Narendra Publishing House, New Delhi.
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- Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2007. *Management of Horticultural Crops*. Parts I, II. New India Publ. Agency.
- Prajapati ND, Purohit SS, Sharma AK and Kumar T. 2006. *A Hand book of Medicinal Plants*. Agro Bios.
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- Purseglove JW, Brown EG, Green CL and Robbins SRJ. 1984. *Spices*. Vols. I, II. Longman.
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- Ranganathan V. 1979. *Hand Book of Tea Cultivation*. UPASI, Tea Res. Stn. Cinchona.
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- Ravindran PN and Madhusoodanan KJ. 2002. *Cardamom, the Genus Elettaria*. CRC press.
- Sera T, Soccol CR and Pandey A Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
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- Thampan PK. 1981. *Hand Book of Coconut Palm*. Oxford and IBH.
- Varmudy V. 2001. *Marketing of Spices*. Daya Publ. House.
- Warrier PK, Nambiar VPK and Ramankutty C. 2007. *Indian Medicinal Plants, a compendium of 500 species*. University Press (India) Private Ltd.
- 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 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 metabolites, 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.
- Das K. 2013. *Essential oils and their applications*. New India Publishing Agency, New Delhi.
- Hammon JM and Yusibov V. 2000. *Plant Biotechnology: New Products and application*. Springer-Verlag.
- Orhan I. 2012. *Biotechnological Production of Plant Secondary Metabolites*. Bentham Science Publishers.
- Raaman N. 2006. *Phytochemical techniques*. New India Publishing Agency, New Delhi.
- Ramawat KG. 2007. *Biotechnology: secondary metabolites: plants and microbes*. Science Publishers.
- Sadasivam S and Manickam A. 1991. *Biochemical methods*. New Age International Publishers.
- 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.
- 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 : 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 <i>In-vitro</i> mass multiplication techniques II <i>In-vitro</i> breeding III Transgenic crops
2	Spice Crops	I <i>In-vitro</i> mass multiplication techniques II <i>In-vitro</i> breeding III Transgenic crops
3	Medicinal and Aromatic Crops	I <i>In-vitro</i> mass multiplication techniques II <i>In-vitro</i> breeding III Transgenic crops IV <i>In-vitro</i> 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, Rauwolfia, 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.
- Chadha KL, Ravindran PN and Sahijram L. Eds. 2000. *Biotechnology of Horticulture and Plantation Crops*. Malhotra Publ. House.
- Choudappa P, Anitha K, Rajesh MK and Ramesh SV. 2017. *Biotechnology of Plantation Crops*. Daya Publishing House, New Delhi.
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- Shukla YM. 2009. *Plant secondary metabolites*. New India Publishing Agency, New Delhi.
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- Williamson R. 1981-86. *Genetic Engineering*. Vols. I-V. Academic Press.

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: Alkalinity, 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 CO₂ 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 PSMA's;
- Pesticide residue analysis in PSMA's.

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.
- Prasad HC, Rao, Sriniv NK, Shivashankar and Seetharamaiah K. 2013. *Climate-Resilient Horticulture: Adaptation and Mitigation Strategies*. Springer.
- Hebbar KB, Kumar SN and Choudappa P. 2017. *Impact of climate change on Plantation Crops*. Daya Publishing House, New Delhi.
- 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.
- Nickell LG. 1983. *Plant Growth Regulating Chemicals*. CRC Press.
- 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.
- Rao Prasada GSHLV, Rao, GGSN and Rao, VUM. 2008. *Climate Change and Agriculture over India*. Kerala Agricultural University, Thrissur.
- Roy B and AK Basu. 2009. *Abiotic stress tolerance in crop plants*. New India Publ. House.
- 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.
- Shanker AK and Venkateswarlu B. 2011. *Abiotic Stress in Plants- Mechanisms and Adaptations*. In tech, Croatia.
- Turner NC and Kramer PJ. 1980. *Adaptation of Plants to Water and High Temperature Stress*. John Wiley and Sons.
- Venkateswarlu B, Shanker AK, Chitra M and Maheswari M. *Crop Stress and its Management: Perspectives and Strategies*. Springer.
- 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.
- E- manual on *Advances in Cashew Production Technology*. ICAR- Directorate of Cashew Research, Puttur –574 202, D.K., Karnataka.
- Gehlot G. 2005. *Organic Farming: Standards, Accreditation, Certification and Inspection*. Agrobios.
- 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.
- Sera T, Soccol CR, Pandey A and Roussos S. *Coffee Biotechnology and Quality*. Springer, Dordrecht.
- 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 PSMA 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 PSMA 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 PSMA 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 PSMA

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 opportunities and channels in PSMA crops
- the entrepreneurship 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.
- E-manual on *Advances in Cashew Production Technology*. ICAR- Directorate of Cashew Research, Puttur-574 202, D.K., Karnataka.
- Holly J and Cheria K. 1998. *The medicinal plant Sector in India*. Medicinal and Aromatic Programme in Asia (MAPPA), New Delhi, India.
- 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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- 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.
- Tyagi SK. 2015. *Spices, Plantation Crops, Medicinal and Aromatic plants-a hand book*. New India Publishing Agency.
- Varmudi. 2001. *Marketing of Spices*. Daya publishing house.
- Ved DK and Goraya GS. 2007. *Demand and Supply of Medicinal Plants in India*. NMPB, New Delhi, FRLHT, Bangalore.

e-Resource

www.nmpb.nic.in



Suggested Journals

Sr. No.	Name of the Journal	ISSN No.
1	<i>Annals of Horticulture</i>	0976-4623
2	<i>Biological Agriculture and Horticulture</i>	2165-0616
3	<i>Current Horticulture</i>	2455-7560
4	<i>European Journal of Medicinal Plants</i>	2231-0894
5	<i>Horticulture Environment and Biotechnology</i>	2211-3460
6	<i>Indian Coconut Journal</i>	0970-0579
7	<i>Indian Horticulture Journal</i>	2347-3029
8	<i>Indian Journal of Arecaunt Spices and Medicinal Plant</i>	0972-2483
9	<i>Indian Journal of Arid Horticulture</i>	2249-5258
10	<i>Indian Journal of Horticulture</i>	0974-0112
11	<i>International Journal of Horticulture</i>	1927-5803
12	<i>International Journal of Horticulture, Agriculture and Plant Sciences</i>	2572-3154
13	<i>International Journal of Innovative Horticulture</i>	2320-0286
14	<i>International Journal of Seed Spices</i>	
15	<i>International Journal of Tea Science</i>	0972-544X
16	<i>Journal of Applied Horticulture</i>	0972-1045
17	<i>Journal of Herbs, Spices, and Medicinal Plants</i>	1540-3580
18	<i>Journal of Medicinal and Aromatic Plant Sciences</i>	0253-7125
19	<i>Journal of Medicinal Food</i>	1557-7600
20	<i>Journal of Medicinal Plant Research</i>	1996-0875
21	<i>Journal of Medicinal Plant Studies</i>	2320-3862
22	<i>Journal of Plantation Crops</i>	2454-8480
23	<i>Journal of Spices and Aromatic Crops</i>	0971-3328
24	<i>Medicinal Plants: International Journal of Phytomedicines and Related</i>	0975-4261
25	<i>Polycyclic Aromatic Compounds</i>	1040-6638
26	<i>Progressive Horticulture</i>	2249-5258
27	<i>Rubber Science (Natural Rubber Research)</i>	2524-3993
28	<i>Spice India</i>	0970-5805
29	<i>The Asian Journal of Horticulture</i>	0973-4767

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Horticultural Sciences

– Post-harvest Management

Preamble

(Post-harvest Management)

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 VCSGUHF, 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: Precooling, 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. Standards and 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 vase life 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. *Handling 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/iibr.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.
- Sunil Pareek (Ed.) 2016. *Postharvest Ripening Physiology of Crops*, CRC Press, ISBN 9781498703802.
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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.
- 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

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- 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.
- Chattopadhyaya 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 and Applications*. 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 Otlis (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 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 SO₂ 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: Nutraceuticals

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 phytonutraceuticals.

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 (Reading/ 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 senescence 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*. Blackwell Publishing, Iowa, USA.
- Seymour G, Taylor J and Tucker G. 1993. *Biochemistry of fruit ripening*. Edited Chapman and Hall, 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.

Websites

<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. Management 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, LD₅₀ 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*.
- George AB. 1996. *Encyclopedia of Food and Color Additives*. Vol. III. CRC Press.
- 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.
- Ötle° 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.faiia.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.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.	<i>Annual Review of Food Science and Technology</i>	ISSN 19411421, 19411413
2.	<i>Comprehensive Reviews in Food Science and Food Safety</i>	ISSN 15414337
3.	<i>Trends in Food Science and Technology</i>	ISSN 09242244
4.	<i>Food Chemistry</i>	ISSN 03088146
5.	<i>Food Microbiology</i>	ISSN 10959998, 07400020

Sr. No.	Name of the Journal	ISSN No.
6.	<i>Postharvest Biology and Technology</i>	ISSN 09255214
7.	<i>Food Research International</i>	ISSN 09639969
8.	<i>Critical Reviews in Food Science and Nutrition</i>	ISSN 15497852, 10408398
9.	<i>Journal of Food Engineering</i>	ISSN 02608774
10.	<i>International Journal of Food Microbiology</i>	ISSN 01681605
11.	<i>Food Control</i>	ISSN 09567135
12.	<i>Innovative Food Science and Emerging Technologies</i>	ISSN 14668564
13.	<i>Food and Bioprocess Technology</i>	ISSN 19355130, 19355149
14.	<i>LWT-Food Science and Technology</i>	ISSN 10961127, 00236438
15.	<i>Journal of Functional Foods</i>	ISSN 17564646
16.	<i>Food Quality and Preference</i>	ISSN 09503293
17.	<i>Journal of Food Composition and Analysis</i>	ISSN 08891575, 10960481
18.	<i>Plant Foods for Human Nutrition</i>	ISSN 09219668, 15739104
19.	<i>Current Opinion in Food Science</i>	ISSN 22147993
20.	<i>Food Packaging and Shelf Life</i>	ISSN 22142894
21.	<i>Journal of the Science of Food and Agriculture</i>	ISSN 10970010, 00225142
22.	<i>International Journal of Food Science and Technology</i>	ISSN 13652621, 09505423
23.	<i>Journal of Food Science</i>	ISSN 00221147
24.	<i>Journal of Food Protection</i>	ISSN 0362028X
25.	<i>Phytochemical Analysis</i>	ISSN 09580344, 10991565
26.	<i>Food Reviews International</i>	ISSN 15256103, 87559129
27.	<i>European Food Research and Technology</i>	ISSN 14382377, 14382385
28.	<i>Biosystems Engineering</i>	ISSN 15375110, 15375129
29.	<i>Agribusiness</i>	ISSN 15206297, 07424477
30.	<i>Journal of Sensory Studies</i>	ISSN 08878250
31.	<i>Journal of Texture Studies</i>	ISSN 00224901
32.	<i>International Journal of Food Properties</i>	ISSN 10942912, 15322386
33.	<i>International Journal of Food Sciences and Nutrition</i>	ISSN 09637486, 14653478
34.	<i>Journal of Food Science and Technology</i>	ISSN 00221155
35.	<i>Advances in Food and Nutrition Research</i>	ISSN 10434526
36.	<i>Journal of Food Process Engineering</i>	ISSN 17454530, 01458876
37.	<i>British Food Journal</i>	ISSN 0007070X
38.	<i>Journal of Food Quality</i>	ISSN 01469428, 17454557
39.	<i>Food Science and Technology International</i>	ISSN 10820132
40.	<i>Irish Journal of Agricultural and Food Research</i>	ISSN 07916833, 20099029
41.	<i>Journal of Food Processing and Preservation</i>	ISSN 01458892
42.	<i>Stewart Postharvest Review</i>	ISSN 17459656
43.	<i>International Journal of Food Science</i>	ISSN 23145765, 23567015
44.	<i>Food Science and Technology</i>	ISSN 01012061, 1678457X
45.	<i>International Food Research Journal</i>	ISSN 19854668
46.	<i>International Food and Agribusiness Management Review</i>	ISSN 15592448, 10967508
47.	<i>Food Science and Technology Research</i>	ISSN 13446606
48.	<i>International Journal of Food Engineering</i>	ISSN 15563758, 21945764
49.	<i>Journal of Horticultural Research</i>	ISSN 23005009, 23533978
50.	<i>International Journal of Postharvest Technology and Innovation</i>	ISSN 17447550, 17447569
51.	<i>Food Technology</i>	ISSN 00156639
52.	<i>Open Nutraceuticals Journal</i>	ISSN 18763960
53.	<i>Advance Journal of Food Science and Technology</i>	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 Executive, Goregaon, East Mumbai-400 063 Email: pathakramkripal@gmail.com Mob.: 09454974422/ 08828486737	Chairman
2.	Dr K M Indires Registrar University of Horticultural Sciences, Bagalkot, Karnataka Email; registrar@unsbagakot.edu.in; indires.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.	<p>Dr Amit Baran Sharangi Professor & Head Department of Spices & Plantation Crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur Email: drabsharangi@yahoo.co.in Mob.: 09433313117</p>	Spices & Plantation crops
7.	<p>Dr Miniraj Professor Department of Plantation Crop and Sciences, Kerala Agricultural University, Thrissur-680 656 Email: n.miniraj@kau.in Mob.: 09388673785</p>	Spices & Medicinal
8.	<p>Dr Laxminarayan Hegde Department of Medical Crops, Arabhavi, University of Horticultural Sciences, Bagalkot Email: hegdela@gmail.com hrspepper@gmail.com Mob.: 08762189133</p>	Horticulture
9.	<p>Dr M. Lakshminarayana Reddy Dean (Hort.) Dr YSR Horticulture University, Venkatarmanagudem West Godavari Dist, Andhra Pradesh-534 101 Email: dh@drysru.edu.in Mob.: 09490402052</p>	Horticulture

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

Forestry

- Silviculture and Agroforestry
- Forest Biology and Tree Improvement
- Forest Products and Utilization
- Forest Resource Management

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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'ble Vice 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 Konkani Krishi Vidyaapeeth, Dapoli, Maharashtra 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 designed 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.
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- 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 succession 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

Silviculture under changing context of forestry- silviculture 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.	Silviculture under changing context of forestry- silviculture 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- <i>Populus species</i> , <i>Neolamarkia cadamba</i> , <i>Eucalyptus</i> sp., <i>Casuarina</i> sp., <i>Tectona grandis</i> , <i>Melia dubia</i> , <i>Dalbergia sissoo</i> , <i>Gmelina arborea</i> , <i>Leucaena leucocephala</i> , <i>Ailanthus excelsa</i> , <i>Azadirachta indica</i> , <i>Swietenia macrophylla</i> , <i>Dendrocalamus</i> sp. and <i>Bambusa</i> 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/or complementarity. 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.	Method for quantifying interactions	01
4.	Principles of 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 Equivalent Ratio, 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 measurement, 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 India*. Surya Publ.
- Julius E. 1982. *Plantation Forestry in the Tropics*. Clarendon Press, Oxford.
- Kumar V. 1999. *Nursery and Plantation Practices in Forestry*. Scientific Publ.
- Luna RK. 1989. *Plantation Forestry in India*. International Book Distributors.
- Prakash R, Chaudhari DC and Negi SS. 1998. *Plantation and Nursery Techniques of Forest Trees*. 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 <i>Eucalyptus</i> , <i>Casuarina</i> , Teak, Sal, Poplar, <i>Acacias</i> 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 biology of 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 plant analysis.
- 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.
- Rammooorthy 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 weed control-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 deficiency symptoms	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: Opportunities 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 <i>vis-a-vis</i> 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 Gadov 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 N₂ 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, Wallingford, 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 Ruhayat 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 soils and 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 relevant 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.	<i>In-vitro</i> 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 Burkhardt H. 2001. *Forest Measurements*. McGraw-Hill Education.
- Barnes BV, Zak DR, Denton SR and Spurr 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, Pandey BN, Singh LB, Pandey PN and Singh RK. 2010. *Text Book of Environmental Pollution*. Narendra Publishing House, Delhi.
- Mikusiński 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.	<i>In situ</i> and <i>ex situ</i> 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. Orchet 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. Orchet 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 \times environment interaction, its significance. Various procedures for the estimation of genotypic \times 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 \times 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 resources. 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 Verlag, New York.
- Bonga JM and Durjan J. 1987. *Cell and Tissue Culture in Forestry Vol. I & II*. Martinus Nijhoff 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, Englewood, 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, <i>In-vitro</i> 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 <i>In-vitro</i> 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 <i>in-vitro</i> 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 understand 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 composition. Mode of action. Phytohormones, auxins, GA, cytokinins, ABA, ethylene. 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-Verlag, 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, ethylene 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.
- William 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 Distributors
- 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		
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/ IIDoctoral Seminar	1+0
FBT 692*	I/ IIDoctoral 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 monoecism 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 menoeicum 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 spp	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 in quantitative genetics, quantitative inheritance, historical aspects, Galton (1869) methods for studying quantitative traits, qualitative and quantitative traits and their inheritance, property of nuclear genes (segregation and linkages). Linkage between major gene and polygenes. Evidence that quantitative trait is inherited in Mendelian 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 heritability 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, metroglyph 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 Russell 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. D² Statistics;
- Principal component analysis;
- Diversity analysis based on RAPD/ SSR.

VII. Suggested Reading

- Mather K and Jinks JL. 1971. *Biometrical Genetics*. Chapman 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 <i>Nicotiana longifera</i>	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 heritability 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.	metrolymph 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 trapping 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 trapping 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.	<i>Agrobacterium</i> 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 CO₂ 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.
- Kozłowski TT. 1971. *Growth and Development of Trees*. Vol. I. Academic Press.
- Kramer PJ and Kozłowski 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 CO₂ 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 CO₂ 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 Kozlowski 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* 4th 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 pelleted 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 Seeds*. Danida Forest Seed Centre.
- Mema NP. 1989. *Principles of Seed Certification and Testing*. Allied Publ.
- Negi SS. 2008. *Forest Tree Seeds*. International Book Distributors.
- 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 pelleted 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 Improvement	08
Supporting Courses		
FOR 511*	I General Statistical Methods and Computer Applications	2+1
	Any other course relevant 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) 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 loads, 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 somnifera*, 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, <i>Gloriosa superba</i> , <i>Valeriana jatamansi</i> , <i>Swertia chirayita</i> , Isabgol, <i>Rauwolfia serpentina</i> , <i>Withania somnifera</i> , Opium Poppy, <i>Aloe vera</i> , Satavar, <i>Stevia rebaudiana</i> , 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, <i>Tagetes minuta</i> , 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- *Rauwolfia*



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- <i>Rauwolfia serpentina</i> , <i>Plantago ovata</i> , <i>Cassia angustifolia</i> , <i>Ocimum</i> sp., <i>Withania somnifera</i> , <i>Valeriana</i> sp., <i>Opium poppy</i> , <i>Gloriosa superba</i> , <i>Andrographis paniculata</i> , <i>Mentha</i> sp., <i>Geranium</i> , <i>Cymbopogon</i> 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 their therapeutic 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 . phytoconstituents Analysis 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 Craftsmen, 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-fertilizers 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-fertilizers 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 <i>in-vitro</i> 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.	<i>In-vitro</i> -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, Electrohomeopathy, 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. *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.
- 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, <i>Aconitum</i> 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 spectrophotometry. Different spectrophotometric methods in chemical analysis. Principle and utilization of different instruments based on spectrophotometric 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 Methods*. 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 spectrophotometry. Different spectrophotometric methods in chemical analysis.	3
2.	Different spectrophotometric methods in chemical analysis. Principle and utilization of different instruments based on spectrophotometric 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 (<i>e.g.</i> 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*. Volume 11: 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, Chlorine free bleaching, organo solve pulping.

UNIT III

Nanotechnology in pulp and paper making. Substitution 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, Chlorine free bleaching, organo solve pulping	7
5.	Nanotechnology in pulp and paper making	4
6.	Substitution 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 <i>vis-a-vis</i> 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 epiphytes. 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 Mensuration*. International Book Distributor.
- Davis LS and Johnson KN. 2005. *Forest Management*. Waveland Press.
- Husch B, Miller CI and Beers TW. 2003. *Forest Mensuration*. John Wiley.
- John AK, Ducey MJ, Beers TW and Husch B. 2017. *Forest Mensuration*. Wiley Blackwell.
- Laar A Van and Akca A. 2007. *Forest Mensuration*. Springer, Netherlands.
- Loetsch I and Haller KE. 1964. *Forest Inventory* Vol. I and Vol II. BLV Verlagsgesellschaft, München, Germany.



- Michael S Philip. 1994. *Measuring Forests and Trees*. CAB International.
 Prodan M. 1968. *Forest Biometrics*. Pergam 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 errors Use 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 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 Fertility*. 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. <i>Frankia</i> 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 of pH, EC, organic carbon	2
4.	Determination of CEC	2
5.	Determination of available N, 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 assessment (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.Agency, 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)
5.	suitability mapping, biomass and carbon mapping, etc. 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	6
6.	GPS: Global Positioning System-meaning, principles, applications, GNSS, IRNS, GAGAN, etc.	5
		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 regions Watershed 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 socio-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 socio-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, nature's 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-governmental 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, Wallingford, 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 impact 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 international treaties 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 <i>legislation</i> (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 CO₂ 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 CO₂ fertilization on productivity, recent techniques for assessing the impact of elevated CO₂ 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 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	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; <i>In-vitro</i> efficacy and <i>In vivo</i> 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.
- Cunningham WP and Cunningham 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 – Addison 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 CO₂ measurement methods;
- Soil Carbon assessment, Soil carbon dynamics;
- Atmospheric CO₂ flux measurements. Exposing plants to elevated CO₂ concentration.

FACE and FATE experiments, Open top chambers and its importance in understanding the effect of increased CO₂ concentration and plant growth;

- Differential responses of species to elevated CO₂ concentrations. Diurnal plant response to light, temperature and CO₂ 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 recognition 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 recognition 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 Methodologies*. 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 Recurrent 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)
3.	Public participation	3
4.	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; watershed associations and groups in villages of India; Government policies, acts and schemes on watershed management

Unit IV

Mathematical modelling of hydrologic processes-precipitation, infiltration, evapotranspiration, 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.

Ghanshyam 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; watershed associations 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 in 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 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/ 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 presentation 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
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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
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Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 1

Sericulture

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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 Agricultural 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 be 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

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- Ganga G and Sulochana Chetty J. 1991. *An Introduction to Sericulture*. Oxford & IBH, New Delhi, p.176.
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- 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.



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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 F₁ seeds, Raising F₁ 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 and breeding 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, ARCB 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), Suriyama Publishers, Bangalore, pp. 25-28.
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- FAO. Manual of sericulture Vol-1.
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- 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.
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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 genera, 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 – Holotype, 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

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- 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 \times Bivoltine), (Bivoltine \times Bivoltine), (Bivoltine \times Bivoltine) \times (Bivoltine \times 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.

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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* - Bhubaneswar, Orissa.
- *Reshme Krishi (Kannada)* - Department of Sericulture, Government of Karnataka, Bangalore.
- *Current Science* – Indian Institute of Science, Bangalore.

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- 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.
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- Tanaka Y. 1964. *Sericology*. Central Silk Board, Bangalore.
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- *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.

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- 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 silk gland 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 germplasm;
- 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 Germplasm 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.
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- Singh BD. 1997. *Plant Breeding: Principles and Methods*. Kalyani Publishers, New Delhi. p. 702.
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- Sreeramareddy G. 1998. *Silkworm Breeding*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.
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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, <i>Exorista bombycis</i> 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 *BmNPV*;
- Isolation and purification of *BmCPV*;
- Isolation and purification of *BmIFV* and *BmDNV*;
- 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 *BmNPV*;
- Study of life cycle, symptoms and diagnosis of *BmCPV*;
- Study of life cycle, symptoms and diagnosis of *BmIFV* and *BmDNV*;
- 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.
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- *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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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.

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

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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 : 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. This highlights 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.

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* - 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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- www.csrtimys.res.in/

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

- Bongale UD. 2003. “Nutritional Management and quality improvement in sericulture”, *Proceedings of the national seminar on mulberry sericulture research in India 26th to 28th November 2001*, P-1037.
- Dandin SB and Giridhar K. 2014. *Handbook of Sericulture 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. Bangalore.
- Rajanna L, Das PK, Ravindran S, Bhogsha 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

- *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.
- *Current Science* – Indian Institute of Science, Bangalore.

Websites

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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

- Bilgrami KS and Dube HC. 1997. *A Textbook of Modern Plant Pathology*. Vikas Publishing House Pvt. Ltd., New Delhi.
- Gautam RD. 1994. *Biological Pest Suppression*. Westvill Publishing House, New Delhi.
- Ghosh MR. 1989. *Concepts of Insect Control*. New Age International Publishers, New Delhi.
- Govindan R, Ramakrishna Naika and Sannappa B. 2004. *Advances in Disease and Pest Management in Sericulture*. Seri Scientific Publishers, Bangalore.
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- Huang E. 2003. *Protection of Mulberry Plants*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.
- 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.
- Rangaswami G. 1996. *Diseases of Crop Plants in India*. Prentice Hall of India Pvt. Ltd., New Delhi.
- Reddy DNR and Narayanaswamy KC. 2003. *Pests of Mulberry*. Zen Publishers, Bangalore.
- Sengupta K, Kumar P, Baig M and Govindaiah. 1990. *Handbook on Pest and Disease Control of Mulberry and Silkworm*. ESCAP, UN, Thailand.
- Singh RN, Samson MV and Datta RK. 2000. *Pest Management in Sericulture*. Indian Publishers, Delhi.
- Sukumar J, Dandin SB and Bongale UD. 1994. *Mulberry Disease and Management*. KSSRDI, Bangalore.

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- *Reshme Krishi (Kannada)* – Department of Sericulture, Government of Karnataka, Bangalore.

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- www.tnau.ac.in/
- www.csrtimys.res.in/

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 Biotechnology, 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

- Burrell MM. 1993. *Enzymes of Molecular Biology*. Humana Press Inc., NewYork.
- 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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- *Bulletins of Sericultural Experimental Station* – Suginami, Tokyo, Japan.
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- *Reshme Krishi (Kannada)* – Department of Sericulture, Government of Karnataka, Bangalore.

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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 silk glands).

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. Silk glands and silk synthesis.



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

- Ather H Siddiqi. 1982. *Experimental Physiology*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.
- Beck SD. 1963, *Animal Photoperiodism*. Holt, Holt Library of Science Series, New York.
- Beck SD. 1980, *Insect Photoperiodism*. Academic Press, New York.
- Gilmour D. 1961, *Biochemistry of Insects*. Academic Press, New York.
- Goldsmith MR and František Marec. 2010. *Molecular Biology and Genetics of the Lepidoptera*. CRC Press Taylor & Francis Group, Broken Sound Parkway NW, USA.
- Govindan Bhaskaran, Stanley Friedman and Rodriguez JG. 1981. *Current Topics in Insect Endocrinology and Nutrition*. Plenum Press, New York and London.
- Morohoshi S. 2000. *Development Physiology of Silkworms*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.
- Saxena AB. 1996. *Hormones of Insects*. Anmol Publications Pvt. Ltd., New Delhi.
- Sturnikov VA. 1976. *Control of Silkworm Development and Sex*. MIR Publishers, Moscow.
- Wigglesworth VB. 1956. *Insect Physiology*. 5th Edn., Rev. Methuen, London.

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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.
- *Reshme Krishi (Kannada)* – Department of Sericulture, Government of Karnataka, Bangalore.

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- www.tnau.ac.in/
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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 haemolymph;
- Quantitative estimations of total soluble sugars in silkworm haemolymph;
- Qualitative tests for proteins and free amino acids in silkworm haemolymph;
- Quantitative estimations of proteins in silkworm haemolymph;
- Qualitative tests for lipids in silkworm haemolymph;
- Quantitative estimations of lipids in silkworm haemolymph;
- Determination of ascorbic acid level in the mulberry leaves;
- Determination of ascorbic acid level in silkworm haemolymph;
- 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

Hamamura Y. 2001. *Silkworm rearing on Artificial Diet*. Oxford & IBH Publishing Co. Pvt., New Delhi. p. 287.

Morohoshi S. 2000. *Development Physiology of Silkworms*. Oxford & IBH Publishing Co. Pvt., New Delhi. p. 287.

Reddy DNR, Narayanaswamy KC, Manjunath Gowda and Jayaramaiah M. 2005. *Morphology and Anatomy of Silkworms*. CVG Books, Bangalore. p. 133.

Tazima Y. 1978. *The Silkworm- An Important Laboratory Tool*. Kodansha Ltd., Tokyo. p. 307.

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- *Journal of Sericultural Science of Japan* – Sericultural Experimental Station, Wade, Suginami-ku, Tokyo, Japan.
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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 of polyploids, 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
- Gopinathan KP. 1992. “Biotechnology in sericulture”, *Current Science*, 62(3): 283-287.

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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	<ol style="list-style-type: none"> 1. Entrepreneurship in sericulture and problems. 2. Sericultural entrepreneurship development in different countries.
2.	Entrepreneurship development in different stages	<ol style="list-style-type: none"> 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	<ol style="list-style-type: none"> 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 dyeing 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, dyeing 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.

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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 <i>Morus</i> 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 disadvantages. Steps in development of polycross hybrids. Advanced generation breeding. Preliminary yield evaluation, multilocal 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 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*”. *Suriyama 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.

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- *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*

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- 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	<ol style="list-style-type: none"> 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	<ol style="list-style-type: none"> 1. Vegetative growth and development of mulberry
3	Plant growth hormones	<ol style="list-style-type: none"> 1. Plant growth hormones and growth regulators
4	Photoperiodism and thermoperiodism	<ol style="list-style-type: none"> 1. Photosynthesis in mulberry 2. Respiration in mulberry
5	Water and nutrient absorption mechanism	<ol style="list-style-type: none"> 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	<ol style="list-style-type: none"> 1. Dormancy in mulberry buds and seeds 2. Biotic and abiotic stress in mulberry
7	Nutrient deficiency symptoms	<ol style="list-style-type: none"> 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 sericulture 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. Bangalore.
- Rajanna L, Das PK, Ravindran S, Bhogेशha 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.

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- *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/
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- www.tnau.ac.in
- www.csrtimys.res.in/

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 in turn influences the cocoon yield is essential in planning silkworm breeding strategies.

V. Aim of the course

The course is 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 moultnism, voltinism 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 moultnism 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.
- Sarker DD. 1998. *The Silkworm Biology, Genetics and Breeding*. Vikas Publishing House Pvt. Ltd., New Delhi. P. 338.
- Sarin C. 1990. *Genetics*. Tata McGraw – Hill Publishing Co. Ltd., New Delhi. P. 528.
- Singh BD. 1997. *Plant Breeding: Principles and Methods*. Kalyani Publishers, New Delhi. P. 702.
- 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.
- Tazima Y. 1978. *The Silkworm: An Important Laboratory Tool*. Kodansha Ltd., Tokyo, Japan. P. 307.

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- *Journal of Sericultural Science Japan*, Japan
- *Korean Journal of Sericultural sciences*
- *Sericologia*, International Sericultural Commission, India.
- *Bulletin of Indian Academy of Sericulture*

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- www.tnau.ac.in
- www.csrtimys.res.in/



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 of Bacterial 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 of Bacterial 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

- Anonymous 1975. *Text Book of Tropical Sericulture*. JOCO, TOKYO, Japan, pp.540-547.
- Aruga H and Tanada Y. 1971. *The Cytoplasmic polyhedrosis virus of silkworm*. Univ.TOKYO press, TOKYO, p.234.
- Devaiah MC and Govindan R. 1995. *Aspergillosis of silkworms*. Silkworm pathology Technical Bulletin no.1,UAS, Bangalore, p. 68.
- Ganga G. 2003. *Comprehensive Sericulture*. vol. 2. Oxford and ub.Co.Pvt.Ltd., New Delhi, p. 430.
- Govindan R, Narayanaswamy TK and Devaiah MC. 1998. *Principles of Silkworm Pathology*. Seri Scientific Publishers, Bangalore, p.420.
- Govindan R and Devaiah MC. 1995. *Densonucleosis and Infectious flacherie of silkworm*. Silkworm pathology technical bulletin no.2, UAS, Bangalore, p.114.
- Govindan R, Narayanaswamy TK and Devaiah MC. 1997. *Pebrine disease of silkworm* UAS, Bangalore, p.51.
- Jameson AP. 1922. *Report on The Diseases of silkworms in India*. Govt. Printing, India.
- Nataraju B, Satyaprasad K, Manjunath D and Aswanikumar C. 2005. *A text book on silkworm crop protection*. Central Silk Board, Bangalore, p.412.
- Shyamala MB, Govindan R, Hadimani AK, Narayanaswamy TK and Ishwarappa S. 1987. *Kenchu - A silkworm flacherie in Karnataka*. UAS Bangalore. Technical series no.49, UAS, Bangalore, p.146.



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- *Journal of Sericultural Science Japan*, Japan
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- www.tnau.ac.in
- www.csrtimys.res.in/

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 i.e., 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 course 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	<ol style="list-style-type: none"> 1. Pests, classification and Damage 2. Pest outbreaks and pest surveillance and forecasting
2.	Pest management	<ol style="list-style-type: none"> 1. Principles and methods 2. Eco-friendly pest management
3.	Bio-ecology and management	<ol style="list-style-type: none"> 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, stem 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 encountered 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 institutions.

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 advocacy to the rearers and growers. This in turn ensures sustainability of sericulture.

X. Suggested Reading

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- Dent DR and Walton MP. 1997. *Methods in Ecological and Agricultural Entomology*. CAB International, Cambridge.
- Gautam RD. 1994. *Biological Pest Suppression*. Westvill Publishing House, New Delhi.
- Ghosh MR. 1989. *Concepts of Insect Control*. New Age International Publishers, New Delhi.
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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*

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- www.tnau.ac.in
- www.csrtimys.res.in/



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, O₂ 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. PTH, 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 esterase activity in egg, haemolymph and silk glands 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 trehalose 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

- Ather H Siddiqi. 1982. *Experimental Physiology*. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi and Calcutta.
- Beck SD. 1963. *Animal Photoperiodism*. Holt, Holt Library of Science Series, New York.
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- Butterworth and Heinemann. 1993. *Cellular Interactions and Immunobiology*. Biotol Series
- Giese AC. 1973. *Cell Physiology*. 4th Edn., Philadelphia, Saunders.
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- Saxena AB. 1996. *Hormones of Insects.* Anmol Publications Pvt. Ltd., New Delhi.
- Sturnikov VA. 1976. *Control of Silkworm Development and Sex.* MIR Publishers, Moscow.
- Wigglesworth VB. 1956. *Insect Physiology.* 5th Edn., Rev. Methuen, London.

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- *Indian Journal of Sericulture*, Central Silk Board, Bangalore
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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 Gametoclinal 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. Silk gland 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

- Burrell MM. 1993. *Enzymes of Molecular Biology*. Humana Press Inc., NewYork.
- 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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- Awasthi AK, Nagaraja GM, Naik GV, Kanginakudru S, Thangavelu K and Nagaraju J. 2004.



- “Genetic diversity and relationships in mulberry (genus *Morus*) as revealed by RAPD and ISSR marker assays”. *BMC Genetics*, 5:1-9.
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- Srivatsava PP, Vijayan K, Aswathi AK and Sarathchandra B. 2004. Genetic analysis of *Morus alba* through RAPD and ISSR markers. *Indian J. Biotech.*, **3**: 527-532.

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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 : 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	Commercially exploited	2. Non-mulberry sericigenous insects 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 improved 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 Machine. Testing and grading of non-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 get 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

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- Ganga G. 2003. *Comprehensive Sericulture*. Volume 2. *Silkworm Rearing and Silk Reeling*. Oxford & IBH, New Delhi, p.429.
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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

- 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 and 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, 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. *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.
- Tripurari Sharan. 1984. *Sericulture and Silk Industry*. Published by Y.K. Sharma, Consortium on Rural Technology, 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.
- *Current Science* – C.V. Raman Institute of Science, Bangalore.
- *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

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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