PONDICHERRY UNIVERSITY

7th PG BOARD OF STUDIES IN AGRICULTURAL SCIENCES

DOCTORAL DEGREE PROGRAMME REGULATIONS AND CURRICULUM (Effective from 2023 – 24)

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE (PAJANCOA&RI)

(A Government of Puducherry Institution)

KARAIKAL – 609 603

PONDICHERRY UNIVERSITY

PUDUCHERRY – 605 014

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REGULATIONS

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL

DOCTORAL DEGREE PROGRAMME

SEMESTER SYSTEM - RULES AND REGULATIONS 2023

01. SYSTEM OF EDUCATION

1.1 The rules and regulations provided herein shall govern Doctoral degree programme offered by Pandit Jawaharlal Nehru College of Agriculture and Research Institute (PAJANCOA&RI), Karaikal under Pondicherry University.

1.2 The duration of Doctoral programme is three academic years (6 semesters). The first year of study shall be the first and second semesters after admission. The second year of study shall be the third and fourth semesters. The third year of study shall be the fifth and sixth semesters.

02. COMMENCEMENT

These regulations shall come into force from the academic year 2023-24.

03. DEFINITIONS

3.1 **'PG Coordinator'** means a teacher of a department who has been nominated by the Head of the Department to coordinate the postgraduate programmes in the department. The coordinator looks after registration, time table preparation, regulation of credit load, maintenance of individual student's files, *etc*.,

3.2 **'Semester'** means a period consisting of 110 working days inclusive of practical examinations but excluding the study holidays and final theory examinations.

3.3 **'Academic year'** means a period consisting of two consecutive semesters including the inter-semester break as announced by the Dean.

3.4 **'Curriculum'** is a group of courses and other specified requirements for the fulfilment of the postgraduate degree programme.

3.5 **'Curricula and syllabi'** refer to list of approved courses for Ph.D programmes wherein each course is identified with a code, a course number, outline of the syllabus, credit assigned and schedule of classes.

3.6 **'Course'** is a teaching unit of a discipline to be covered within a semester having a specific number and credits as detailed in the curricula and syllabi issued by the University.

3.7 **'Major Course'** means the subject of Department or discipline in which the student takes admission. Among the listed courses, the core courses compulsorily to be registered shall be given '*' mark.

3.8 **'Minor Course'** means the course closely related to a student's major subject.

3.9 **'Supporting Course'** means the course not related to the major course. It could be any course considered relevant for student's research work or necessary for building his/her overall competence.

3.10 **'A credit'** in theory means one hour of class room lecture and a credit in practical means two and half hours of laboratory or workshop or field work per week.

Explanation : A 1+1 course (2 credits) means 1 hour theory and 2.5 hours practical per week.
A 1+0 course (1 credit) means 1 hour theory per week

3.11 **'Credit Load'** of a student during a semester is the total number of credits of all the courses including common courses, that a student register during that particular semester.

3.12 **'Grade Point'** means the total marks in percentage obtained in a course divided by 10 and rounded to two decimals.

3.13 **'Credit Point' means** the grade point multiplied by the credit load of the course.

3.14 **'Overall Grade Point Average (OGPA)'** means the total credit point of the courses completed by the student divided by total credits of the courses studied. The OGPA is to be worked out by rounding to nearest two decimals.

3.15 **'Arrear examination'** is an examination written for the failed course by a student without undergoing regular classes in that course.

3.16 **'Transcript Card'** is the consolidated report of academic performance of a student issued by the University on completion of the curriculum fulfilment. The format of Transcript Card is furnished in *Annexure-1.*

04. DOCTORAL PROGRAMMES

The Doctoral programme offered in the College is as follows:

4.1 DOCTOR OF PHILOSOPHY [Ph.D.]

Ph.D. Agricultural Economics
Ph.D. Agronomy
Ph.D. Genetics and Plant Breeding
Ph.D. Soil Science
Ph.D. Vegetable Science

05. ADMISSION

5.1. Eligibility for admission:

i. Candidates seeking admission to Doctoral degree programme should have a two year Master's degree from State Agricultural Universities (SAU) or from other institutes accredited by NAEAB (ICAR) alone are eligible to apply for the doctoral program.

ii. Candidate who has undergone the course credit system with an OGPA of 3.00 out of 4.00 or 7.00 out of 10.00 or 70 percent aggregate alone is eligible to apply for Doctoral degree programme in this Institute.

iii. Prescribed minimum qualification from a recognized University for admission to Doctoral degree programme:

Requirement for Doctoral Degree

Sl. No.	Degree	Requirement for Doctoral degree programs
1.	Ph.D. Agricultural Economics	M.Sc. (Agri.) Agricultural Economics
2.	Ph.D. Agronomy	M.Sc. (Agri.) Agronomy
3.	Ph.D. Genetics & Plant Breeding	M.Sc. (Agri.) Plant Breeding and Genetics / M.Sc. (Agri.) Genetics and Plant Breeding / M.Sc. (Agri.) Plant Genetic Resources
4.	Ph.D. Soil Science	M.Sc. (Agri.) Soil Science / M.Sc.(Agri.) Soil Science and Agricultural Chemistry
5.	Ph.D. Vegetable Science	M.Sc. Vegetable Science/ M.Sc. (Hort.) Vegetable Science

5.2. Application for admission:

i. Application for admission shall be made in the prescribed form to be downloaded from the website of the college (www.pajancoa.ac.in) after notification is issued to this effect.

ii. The admissions shall be regulated and made in accordance with the admission rules and regulations in force.

5.3. Method of selection:

i. The admission to the Doctoral Programme is based on the marks / rank obtained in ICAR's All India Entrance Examination (AIEEA) / ICAR's All India Competitive Examination (AICA-SRF (Ph.D.) /CUET.
ii. Number of seats in each Ph.D. degree programme shall be decided as per availability of recognised Ph.D. guide.
iii. Seats are reserved for candidates belonging to SC/ST, OBC as per the norms of Govt of Puducherry.

5.4. Admission procedure:

i. All admissions made by this Institute are provisional and subject to the approval of the University.

ii. The candidates who have offered admission should report to the college on or before the due date mentioned failing which their right of admission is forfeited.

06. LANGUAGE REQUIREMENT

The medium of instruction is English. The Doctoral students should have adequate knowledge in English to read, write and speak in English and able to prepare high quality research papers in English.

07. RESIDENTIAL REQUIREMENT

i. The minimum and maximum duration of residential requirement for Ph.D. Programmes shall be as follows

Duration of Residential Requirement	
Minimum	Maximum
3 Academic Years (6 semesters)	7 Academic Years (14 Semesters)

Student may be allowed to discontinue temporarily only after completion of coursework

ii. In case a student fails to complete the degree programme within the maximum duration of residential requirement, his/ her admission shall stand cancelled.

08. REGISTRATION

The list of courses offered to the student in each semester shall be sent by the Dean to the Controller of Examinations for Registration of examination as instructed by the University from time to time.

09. DISCONTINUANCE AND READMISSION

As per University Regulations.

10. ADVISORY COMMITTEE

10.1. Each Doctoral student shall have an advisory committee to guide the student in carrying out the programme. Only recognized teachers are eligible for teaching Ph.D. courses and guiding thesis research.

10.2. Chairperson/Guide:

i. The approved guides by the University only can be the guide for the students.
ii. Every student shall have a Chairperson of the Advisory Committee who will be from his/her major field of studies.
iii. The appointment of chairperson shall be made by the Head of the Department.
iv. The Head of the department will allot the Doctoral students among the recognized guides.
v. A teacher should have a **minimum of three years** of service before retirement for allotment of Doctoral students.
vi. At any given time, a PG teacher shall not be a Chairperson of Advisory Committee (including Master's and Ph.D. programmes) for more than five students.

10.3. Chairperson/ Co-guide/ Member from other collaborating University/ Institute/ Organization:

i. In case the Chairperson has less than 3 years of service he can be allowed to act as Co-guide / Member of the Advisory Committee.
ii. The University / Institute may enter into Memorandum of Understanding (MOU) with other Universities / Institutions / Organizations for conducting research. However, to

include faculty of Pondicherry University to act as Co-guide / Member of the Advisory Committee Memorandum is not required.

iii. The proposed faculty member from the partnering institution can be allowed to act as Co-guide / Member of Student Advisory Committee

Note: In special cases the proposed faculty member from the partnering institution can be allowed to act as Chairperson.

10.4. Members:

i. The advisory committee shall comprise of a chairperson and three members. One member will be from the concerned department and other members from the related field of thesis research from other departments / discipline 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.

ii. External experts may be included as member/co-guide in the advisory committee based on the need and expertise of the member, without any financial commitment to the College so as to improve the quality of the thesis. The external expert member proposed should meet the minimum qualification required and the proposal is to be approved by the Dean.

10.5. Formation of advisory committee:

i. For Doctoral Programme the advisory Committee Chairperson and members will be in the cadre of Professors, Associate Professor and Assistant Professors.

ii. A proposal for the formation of the advisory committee (**Form 1**) of the student, shall be forwarded by the Head of the Department to the Dean for approval within one month from the commencement of the first semester.

10.6. Changes in advisory committee:

i. The proposal for changes in the advisory committee (**Form 1a**) is to be sent to the Dean for approval, if it is keenly felt that such changes are absolutely necessary. The reason for such change should be indicated.

ii. The changes may be effected immediately, when the existing members are transferred elsewhere or resigned or retired.

10.7. Absence of member during qualifying/final viva-voce examination:

i. Conducting qualifying and final viva voce examination in the absence of members is not allowed.

ii. Under extra-ordinary circumstances if the qualifying/ final viva-voce examination to Doctoral student has to be conducted in the absence of one or two advisory committee members, permission to conduct the examination by co-opting another member in such contingencies should be obtained from the Dean in advance.

iii. The co-opted member should be from the same department of the member who is not attending the examinations.

iv. In the absence of the Chairperson of advisory committee, respective Heads of Departments should act as Co-chairperson with prior permission of Dean.

10.8. Duties and responsibilities of the advisory committee:

i. Drawing the student's academic plan for Doctoral programme.
ii. Guidance throughout the programme of the student.
iii. Guiding the student in selecting a topic for thesis research and seminar.
iv. Evaluation of research and seminar credits.
v. Correction and finalization of thesis draft
vi. The members should meet together along with the student for all the above purposes and sign the appropriate documents.

11. PLAN OF COURSE WORK

The student's plan for Doctoral course work **(Form 2)** drawn up by advisory committee shall be sent to the Dean before 55th working day during the first semester.

12. PROGRAMME OF RESEARCH WORK

The proposal for research programme of the student, in the prescribed format **(Form 3)** and approved by the advisory committee, shall be sent for approval of the Dean before the end of the semester in which the research credits are registered for the first time or before taking up of the research work whichever is earlier.

13. CREDIT REQUIREMENTS

13.1. Minimum credit requirement: A Doctoral student should complete a minimum of 100 credits as detailed below for award of the degree.

Credit Requirements

Details	Credits
i) Course Work	
Major Courses	12
Minor Courses	06
Supporting Courses	05
Seminar-2 nos. each 0+1 credit	02
ii) Thesis Research	75
Total Credits	**100**

13.2. Maximum credit load: A Doctoral student can register a maximum of **22 credits per semester** including seminar and research. However, research credits registered per semester shall not exceed **20 credits**.

13.3. **Comprehensive qualifying examination and thesis:** A Doctoral student should successfully complete a comprehensive qualifying examination and thesis in the major field of study and submission of thesis thereon.

13.4. **Extra Credits:**

i. Over and above the prescribed minimum credit requirements, extra course credits up to a maximum of six can be registered for Doctoral programme.
ii. The extra credits registered will be accounted for calculation of OGPA.

14. ATTENDANCE REQUIREMENTS

14.1. A minimum of 80 per cent attendance separately in theory and practical of the concerned course is a must. However, the attendance may be condoned up to 10%, under extra-ordinary situation, by the Dean based on the genuineness of the case and upon the recommendation of the Advisory Committee and Head of the Department, failing which the student shall not be permitted to appear for both final theory and final practical examinations in the course concerned and grade 'E' (incomplete) will be awarded.

14.2. The student securing 'E' grade in a course must re-register the course when offered again with the permission of the University.

14.3. Calculation of Attendance

a) THEORY:

i. Number of classes conducted for a course from the first instructional day as per the time table to the last theory class of that semester is to be construed as the total number of theory classes conducted by the course teacher.

b) PRACTICAL:

i. Number of practical classes conducted for a course from the first instructional day as per the time table to the last practical class of that semester is to be construed as the total number of practical classes conducted by the course teacher.

ii. The final practical examination will be conducted after the completion of 96 working days as per the schedule.

iii. The attendance for practical examination shall not be counted for calculating the attendance for practical.

iv. For calculating 80 percent attendance the number of instructional days may be calculated only from the date of joining of the student for first year first semester only.

v. The students failing to attend the classes / examinations on non-official ground will be treated as absent.

vi. Students deputed for sports, cultural meets etc. with prior permission of the Dean of the college shall be given attendance for the period of absence. However, students under this category must have attended a minimum of 50 per cent classes in the total theory and practical classes conducted.

15. EVALUATION OF STUDENT'S PERFORMANCE

15.1. Distribution of marks:

i. All students shall abide by the rules for evaluating the course work under the semester system of education, as prescribed from time to time by the university. The weightage of Theory and Practical shall be in the ratio of 80:20 respectively.

ii. The student should secure a minimum of 50 per cent marks in theory as well as in practical with an aggregate of 70 per cent to secure a pass in a course.

iii. In each course, examinations will be conducted for 100 marks as detailed below.

Examination	Courses with theory & practical	Courses with only theory
Term Paper	20	20
Final Theory Examination	60	80
Final Practical Examination	20	-
TOTAL	**100**	**100**

15.2. Final Theory Examination:

i. An examination schedule prepared by the Dean for the final theory examinations shall be the final. The schedule of examinations shall be adhered strictly.

ii. The duration of final theory examinations will be three hours.

iii. The final theory examinations shall be **conducted and evaluated internally** by the course teacher.

iv. Re-valuation/Re-totalling is not allowed for theory examinations.

v. No re-examinations shall be allowed in the events of students' strike, boycott, walkouts, and medical grounds or what-so-ever may be the reason.

15.3. Postponement of Final Theory Examination:

Whenever the Government declares holidays on the dates of final examinations, the examinations that fall on the dates shall be postponed to the dates after the last examination as per the original examination schedule.

15.4. Final Practical Examination:

i. The Head of the Department will announce the schedule of final practical examinations.

ii. The final practical examinations shall be conducted after the completion of minimum of 96 working days.

iii. Submission of bonafide practical records and term paper in complete form and certified by the Course Teacher is a pre-requisite for appearing in a practical examination failing which 'F' grade will be awarded.

iv. The final practical examination of the course shall be conducted and evaluated by the course teacher.

v. The duration of final practical examination shall be two and half hours.

vi. The practical examination marks should be communicated to the Dean within ten days after the conduct of respective final practical examinations.

15.5. Arrear examination:

i. Arrear examination is permitted for the final theory and final practical examination.

ii. The students are permitted to write the arrear examinations along with the regular semester examination

iii. The prescribed arrear examination fee should be paid on or before the specified date.

iv. A student is permitted to write the final theory and practical examinations (Term paper marks shall be retained as such) only two times during 3 years duration excluding the regular final examination.

v. In the event of a student failing to secure pass in the two arrear examinations permitted, he/she has to re-register the course along with juniors as and when the course(s) are

offered with the permission of the University on payment of the prescribed Re-registration fee.

vi. The Registration for the arrear examination shall be done on the date specified by the Dean. Each registration is considered as an attempt even if the student is absent for the examination.

15.6. Late comer in Examinations:

i. The students who are late by 30 minutes shall not be allowed to enter the examination hall.

ii. Similarly, no student will be allowed to leave the examination hall within 30 minutes of the commencement of the examination.

15.7. All theory examinations shall be conducted in the Examination hall of the College. The student should necessarily come to the examination hall(s) with Identity card and hall tickets and produce the same to the examiner(s)/invigilator(s), failing which the student shall not be allowed to write the examinations.

15.8. Hall tickets:

i. The students shall be issued with hall tickets for writing their final theory/practical examinations.

ii. The PG coordinator of the concerned department shall prepare the hall tickets, get the approval of the Head of the Department and issue to the students.

iii. In case of loss of hall tickets by the students, duplicate hall ticket shall be issued on payment of prescribed fine.

iv. The students who have lost/missed their hall tickets shall apply to the Head of the Department for getting a duplicate hall ticket.

15.9. Evaluation of Course Work:

i. Each course shall carry a maximum of 100 marks. The results of the course shall be indicated by the grade points ranging from 0 to 10.

ii. The total marks in percentage obtained by the student in a course shall be divided by 10 and rounded to two decimal places to get the grade point.

iii. The minimum Grade Point to be secured for the successful completion of a course shall be 7.00.

iv. Securing a grade point less than 7.00 in a course will be treated as 'F' (Failed) and the Grade Point will be 0.00 for calculating the GPA/OGPA. The following symbols may be used

E - INCOMPLETE (Lack of 80 % Attendance)
F - FAILED
RR - RE-REGISTRATION
RE - RE- EXAMINATION
EE - INCOMPLETE FOR REASONS OTHER THAN ATTENDANCE

15.10. Question paper pattern for theory examinations:

15.10.1. The question paper pattern for final theory examinations are indicated below:

Part	Type of question	Number of question	Number of questions to be answered	Mark per question	Total marks
Courses with theory and practical (1+1 or 2+1 courses) (60 Marks & 3 hours duration)					
A	Definitions/Concepts	12	10	1.0	10
B	Paragraph answers	7	5	4.0	20
C	Essay type answers (**EITHER OR** type) - One main question from each unit shall have one choice	5	5	6.0	30
	TOTAL				**60**
Courses with only theory (1+0 or 2+0 courses) Final Theory Examination (80 Marks & 3.0 hours duration)					
A	Definitions/Concepts	18	15	1.0	15
B	Paragraph answers	7	5	5.0	25
C	Essay type answers (**EITHER OR** type) - One main question from each unit shall have one choice.	5	5	8.0	40
	TOTAL				**80**

15.10.2. Question paper pattern for final Practical Examination: The following distribution of marks shall be adopted in conducting the final practical examinations.

Details	Courses with Theory and Practical
Practical Field work / Lab Work / Written exam	20
Total	**20**

For conducting practical examinations, the type and number of questions can be decided by the course teacher.

15.11. Term Paper:

i. Submission of a term paper by the students is a must.

ii. The term paper topics shall be assigned by the course teacher. Term papers should cover a wide range of subjects within the course limits.

iii. The term paper shall be evaluated by the course teacher.

15.12. Return of valued answer papers:

i. The valued answer papers of final theory and practical examination shall be shown to the students after the examination. Discrepancies if any, in awarding marks, the student can approach the teacher concerned immediately for rectification.

ii. The answer paper should be retained by the course teacher for six months and then disposed off.

iii. The same is applicable to arrear examination also.

16. COMPREHENSIVE QUALIFYING EXAMINATION

16.1.

i. Only those postgraduate students who successfully complete the comprehensive qualifying examination shall be admitted to candidacy of the degree.

ii. The qualifying examination consists of written and oral examination in major subjects only and the students should be allowed after completion of 80 per cent of total course credit load including major and minor courses.

iii. The qualifying examination shall be conducted only in the major courses as per the norms given below:

Question paper setting	-	External
Evaluation of answer book	-	External
Qualifying marks	-	60 per cent
Viva Voce	-	External
Grading	-	Satisfactory/Not Satisfactory

16.2. Selection of examiner:

i. The Head of the concerned Ph.D. Department shall send a panel of three examiners for conducting the comprehensive qualifying examination (**Form 4**).

ii. The Controller of Examinations, shall nominate the external member from the panel for conducting qualifying examination of all the students of the department. However, the University can draw its own panel of examiners.

iii. The panel of examiners for qualifying examinations shall be given by the Head of the Department three months before the date of completion of the student's course work.

16.3. Written examination:

i. Normally the qualifying examination shall be completed before the end of third semester of the doctoral programme.

ii. The controller of examination shall conduct the qualifying written examination.

iii. The written examination shall be conducted for major courses only.

iv. The question paper for the written examination shall be of 3 hours duration and each question need not be restricted to any particular topic in a course but it should be a comprehensive of the syllabus of each course.

v. The question paper pattern for the written examination is given below.

Part	Type of question	Number of questions	Number of questions to be answered	Mark per question	Total marks
A	Paragraph answers	7	5	5	25
B	Essay type answers	7	5	15	75
				TOTAL	100

16.4. Oral examination:

i. Only those students who secure 'SATISFACTORY' grade in written qualifying examination shall be permitted to attend the oral qualifying examination
ii. The advisory committee shall conduct the oral examination with one external examiner, who sets the question paper and evaluated the written qualifying examination.
iii. The performance of the student(s) in the qualifying viva-voce examination shall be graded as "Satisfactory" or "Not satisfactory".
iv. If the performance of the student is "Not Satisfactory" in the oral examination, he/she has to appear for the oral examination again.

16.5. Failure/absence in qualifying examination:

i. A student is permitted to write the qualifying examination only three times including the regular attempt.
ii. A student who fails or absents in the comprehensive qualifying written/viva-voce examination shall apply to the University with the recommendation of the Chairperson of the advisory committee, Head of the Department and the Dean for re-examination.
iii. A student who applies for re-examination should attend written examination and viva-voce after paying the prescribed re-examination fee.
iv. Re-examination shall not take place earlier than three months after the previous qualifying examination.
v. If a student fails even in the second re-examination (third attempt), he/she cannot continue as a student in the University for Award of Doctoral degree in the University.
vi. The research credits registered in the final semester shall not be evaluated unless he/she successfully completes the qualifying examination.

16.6. Communication of results of qualifying examination:

i. The Chairperson of the advisory committee shall act as Chairperson for the examination committee.
ii. The Chairperson of the advisory committee shall be responsible for communicating the results of the examination to the Controller of Examinations in the prescribed format (**Form 5**).

17. CREDIT SEMINAR

17.1. Seminar is compulsory for all the Doctoral students and each Doctoral student should register and present two seminars with 0+1 credit.

17.2. Registration of seminar credits is not allowed in the first year.

17.3. Seminar topic:

i. The seminar topic should be only from the major field and should not be related to the area of thesis research.

ii. The seminar topics are to be assigned to the students by the Chairperson at the beginning of the semester in which he/she registers seminar credits and the progress made by the student should be monitored.

17.4. Evaluation of seminar:

i. The students should prepare a seminar paper after reviewing all the available literature and present the seminar after completion of 80% attendance in the semester in the presence of the Advisory committee, staff and Doctoral students of the concerned department.

ii. The circular on the presentation of the seminars by the Doctoral students may be sent to other departments to enable those interested to attend the same.

iii. After carrying out the corrections/suggestions, the student should submit two copies of the seminar papers, one to the Chairperson and the other to the department.

iv. The performance of the student in the credit seminar has to be evaluated for 100 marks by the advisory committee. Grade Point may be given based on the following norms:

Particulars of Marks

Sl. No.	Description	Marks
1.	Synopsis of the Seminar	10.00
2.	Presentation	
	a) Introduction	05.00
	b) Style Clarity	10.00
	c) Sequence and Organization	05.00
	d) Topic Coverage	20.00
	e) Effective use of Audio Visual Aids	05.00
	f) Time Management	05.00
	g) Response to Question during discussion	10.00
3.	Report	30.00
	TOTAL	**100**

17.5. The students who fail to present the seminar must be awarded 'F' grade and the student should again register the seminar credits and present the seminar in the subsequent semester.

17.6. Presenting a seminar is a must for the award of the degree.

18. THESIS RESEARCH

18.1. Selection of topic:

i. With the guidance of the advisory committee the students should identify the tentative area of research and include it in the plan of work.

ii. The advisory committee should guide the students in selecting a specific topic in the identified area and preparing a detailed proposal. While selecting the topic for thesis research, the specialization and competency of teachers, thrust area identified by the department, external funded schemes operated in the department and also the aptitude of the student may be taken into consideration.

iii. The topic for thesis research for the students of Doctoral programme should be of such a nature as to indicate a student's potentiality for conducting research and to train him in research.
iv. The thesis shall be on a topic falling within the field of the major specialization and shall be the result of the student's own work.
v. A certificate to this effect duly endorsed by the Chairperson of the Advisory Committee shall accompany the thesis.

18.2. Research Colloquium:

i. The research proposal has to be presented by the student in a colloquium organized by the Head of the department/Dean to get the opinion/ suggestions of the scientists of the concerned/other departments for improving it and approved by the Dean
ii. Three copies of the research proposal in the prescribed format (**Form 3**) should be sent to the Dean through the Head of the department for approval before the end of the semester in which the student has registered research credits for the first time or before taking up the field / laboratory experiments whichever is earlier.

18.3. Evaluation of thesis research:

i. After assigning the research problem, for each semester the student has to submit a detailed programme of work to be carried out by him/ her during the semester in the prescribed proforma (**Proforma 1- Part A**). After scrutiny and approval, a copy of the programme has to be given to the student for carrying out the work during the semester.
ii. Attendance register must be maintained in the department for all the students to monitor whether the student has 80% of attendance in research.
iii. After completion of 80% attendance for research and on or before the last day of the semester, the advisory committee should evaluate the progress of research work as per the approved programme and monitoring register (**Proforma 6**) and award '**SATISFACTORY** or **NOT SATISFACTORY**' depending upon quantity and quality of work done by the student during the semester. The procedures of evaluating research credits under different situations are explained hereunder.

a. SITUATION I: The student has completed the research credits as per the approved programme and awarded '**SATISFACTORY**' by the advisory committee. Under the said situation the student can be permitted to register fresh block of research credits in the subsequent semester. If the student is awarded '**NOT SATISFACTORY**' he/she has to reregister the same block of research credits in the subsequent semester.

b. SITUATION II: If the student has not secured the minimum attendance of 80 percent, then the grade 'E' should be awarded. The student has to reregister the same block of research credits for which 'E' grade was awarded in the subsequent semester with prior permission from the University. Until the completion of re-registered credits, the student should not be allowed to register for fresh block of research credits.

c. SITUATION III: The student could not complete the research work as per the approved programme of work for reasons beyond his/her control such as,

- Failure of crop.
- Incidence of pests or disease or lack of such necessary experimental conditions.
- Non-availability of treatment materials like planting materials chemicals, *etc*.
- Any other impeding/unfavorable situation for carrying out research.

Under the said situations III, Grade 'E' shall be awarded. The student has to

reregister the same block of research credits for which 'E' grade was awarded in the subsequent semester with prior permission from the University. Until the completion of re-registered credits, the student should not be allowed to register for fresh block of research credits.

d. SITUATION IV: When the student failed to complete the work even in the 'Second time' registration, the student will be awarded '**NOT SATISFACTORY**' and he/she has to reregister the same block of research credits in the subsequent semester with the prior permission from the University.

e. SITUATION V: If a student cannot complete qualifying examination till the end of final semester, the research credits registered in the final semester shall not be evaluated unless he/she successfully completes the qualifying examination. The research credits registered by the student during the final semester shall be evaluated within 15 days from the date of declaration of result of the qualifying examination.

f. SITUATION VI: If a student secures 'F' grade in one or more course(s) and cannot complete the course(s) till the end of final semester, the research credits registered in the final semester shall not be evaluated unless he/she successfully completes the course(s) in which he/she secures 'F' grade. The research credits registered by the student in the final semester shall be evaluated within 15 days from the date of declaration of result of the failed course(s). If the student fails to complete the course even in 1+2 attempts, 'E' grade shall be awarded for the research credits registered in the final semester and the student has to re-register the same block of research credits along with the re-registration of failed courses, with the approval of the University.

18.4. Re-registration of research credits: Students have to obtain prior permission of the University for re-registering the research credits. However, the University can permit the registration of research credit only three times. Permission to register for the fourth time shall be given only by the Academic Council.

19. SUBMISSION OF THESIS

19.1.

i. The research credits registered in the last semester of Doctoral programmes should be evaluated only at the time of the submission of thesis by the advisory committee. Students can submit the thesis at the end of the final semester. The list of enclosures to be submitted along with the thesis is furnished in ***Annexure-4***.

ii. If a Doctoral student has completed the thesis before the closure of the final semester, the Chairperson can convene the advisory committee meeting and take decision on the submission of the thesis provided the student satisfies 80 per cent attendance requirement.

iii. During submission of thesis for external evaluation, it is mandatory to enclose certificate for plagiarism check under reference management (**Proforma 15**) as per UGC norms.

iv. Copy of the thesis to be sent for evaluation should be submitted in paper pack.

v. After incorporating the suggestions of the examiners and those received at the time of viva-voce, the thesis should be submitted to the College/university in hard bound copies (four copies) and soft copies (in pdf format) in CDs (two copies).

19.2. Grace period:

i. Students can avail a grace period up to three months for submission of thesis after the closure of final semester by paying prescribed fine.
ii. If a student is not able to submit the thesis within three months grace period, the student has to re-register the credits in the forthcoming semester.
iii. The student(s) who re-register the credits after availing the grace period will not be permitted to avail grace period for the second time.
iv. The Heads of the Department can sanction the grace period based on the recommendation of advisory committee and a copy of the permission letter along with the receipt for payment of fine should accompany the thesis while submission.

19.3. Re-registration and submission of thesis: The minimum of 80% attendance requirement for submitting the thesis after re-registration need not be insisted for those students who have fulfilled the minimum academic and residential requirement i.e. 3 years (6 semesters) and completed the minimum credit requirements with 80% attendance.

19.4. Publication of articles: Part of thesis may also be published in advance with the permission of the Chairperson. If any part is published, the fact should be indicated in the certificate given by the Chairperson that the work had been published in part/ full in any scientific or popular journals, proceedings, etc.

- **It is encouraged to publish minimum two research articles from the Doctoral thesis work**.
- Publication of two research articles should be made in UGC listed journals. The chairperson can also encourage the scholars to publish in high impact factor journals.

20. EVALUATION OF THESIS

20.1. The thesis submitted in partial fulfilment of a Doctoral degree shall be evaluated by two external examiners nominated by the Controller of Examinations, upon recommendation of the Dean, from a panel of five names of specialists (**Form 6**) in the particular field in India.

20.2. An oral examination will be conducted by the Advisory Committee after the thesis is recommended by the external examiners and carrying out the corrections/suggestions made by the external examiners by the student.

20.3. An oral examination (public defence) will be conducted by the Advisory Committee after the thesis is recommended by the external examiners besides the student should have carried out the corrections/suggestions made by the external examiners (**Form 8**). Public defence for doctoral students shall be conducted by the Chairperson of the advisory committee with the addition of one of the External Examiners nominated by the University on the working days in the presence of a **Proctor** appointed by the Dean to oversee the entire proceedings as a part of internal quality monitoring. The Heads of the Department shall nominate one Professor as a 'Proctor' from any Departments other than his department and it shall be approved by the Dean. In addition, the proctor has to sign in the public defence report. The Chairperson shall send the recommendations of the advisory committee along

with necessary certificate/documents in duplicate to the Dean. The thesis shall be finally accepted for the award only after the student satisfactorily completes a public defence.

20.4. The aims of the Ph.D thesis defence are to evaluate the candidate's academic competence, performance and his/her ability to interpret and discuss the undertaken research independently. The candidate is obliged to give a short lecture supporting his/her PhD thesis, publications and future research outlines. The final evaluation determines the candidate's academic results and conclusions i.e how clearly does he/she achieved the research objectives, solved the problems and obtained solutions; how logically the results are interpreted and further research possibilities outlined. Questions posed and clarification provided by the candidate during the defence gives an impression about the candidate's ability in academic debate.

20.5. The Chairperson shall send the recommendations of the advisory committee (**Form 7**) along with necessary certificate/documents in duplicate to the Dean. On the unanimous recommendation of the committee and with the approval of the University, the degree shall be awarded to the candidate.

20.6. The result declaration proposal will be sent by the Dean to the Controller of Examinations.

20.7. i. In case of difference of opinion on the acceptability of thesis for the award, the Controller of Examination may on the special recommendation of the advisory committee, refer the thesis for scrutiny and independent judgment to a third external expert chosen by him.

ii. If the third external expert recommends the thesis for acceptance, this recommendation may be accepted.

iii. If however, the opinion is still not uniform the degree shall not be awarded.

iv. In the above case, the advisory committee shall send their recommendation to the Dean within one month from the date of receipt of the thesis for scrutiny.

21. REVISION OF THESIS

21.1. If an examiner recommends for revision of thesis the following norms will be adopted.

i. For revision of draft, the thesis should be resubmitted after a minimum of one month from the date of communication from Dean.

ii. If the revision is recommended for repeating lab experiments, field trial etc., resubmission must be after a minimum of six months.

21.2. At the time of resubmission, the advisory committee should give a certificate for having carried out the corrections/recommendations. The resubmitted copies of thesis should have incorporated the necessary corrections as indicated by the external examiners. (**Form 8**)

22. FAILURE TO APPEAR FOR PUBLIC DEFENCE/NON-SUBMISSION OF THESIS AFTER PUBLIC DEFENCE

22.1. If a candidate fails to appear for public defence on the date fixed by the Chairperson the following are the time-frame and penalty.

The defence must be completed within **seven years from the date of** first registration for the degree program. An amount of penalty/ fine of Rs.5,000/-shall be levied to the candidate.

22.2. After successful completion of public defence if a student fails to submit the corrected version of the thesis within 15 days he/she shall be levied a fine of Rs. 5,000/- at the time of sending the proposal for result declaration.

23. RESULT NOTIFICATION

23.1. After the completion of each semester, the student shall be given the Report Card by the University.

24. MALPRACTICES IN EXAMINATION AND MISCONDUCT OF STUDENTS

24.1. The Dean of the College shall be responsible for dealing all cases of unfair means by students in writing records, term papers and examinations.

24.2. The invigilator or the course teacher concerned shall report each case of unfair means with full details of evidence and written explanation of the student concerned to the Dean immediately.

24.3. The Dean shall take appropriate action on receipt of the report and the penalty may be as indicated below.

i. Students found using unfair means during the final theory/practical examination will be deemed to have failed in all the courses in that semester and also debarred from the college for the next semester.

ii. For using unfair means of a serious nature (which will be decided by committee nominated by the Dean) warranting higher penalties than those indicated in clauses **24.3 (i)** and **24.3 (ii)** the student may be debarred from the College for a period of two semesters or more or expelled permanently after obtaining the orders of the University. In such cases, the students concerned shall not be allowed to sit for the remaining examinations in the concerned course or other courses.

iii. Details of each case together with all material evidence and recommendations of the Dean shall be communicated forthwith to the Registrar of the university. The Dean shall issue necessary orders and report each case falling under clauses **24.3 (i), 24.3 (ii)** and **24.3 (iii)** to the Registrar immediately.

24.4. Ragging rules: Students found involved in ragging or in any other misconduct, or on a report received from the affected student(s), the Dean shall immediately expel the concerned student(s) against whom the report is received from Hostel/College, for the current semester and the Dean shall further constitute a committee to probe and conduct enquiry into the matter and based on the report from the committee, shall pass the final orders on merit of the case within three working days. As per the order of the Supreme Court of India, the punishment for ragging may take the shape of (a) Withholding scholarships or other benefits (b) debarring from representation in events (c) withholding results (d) suspension or expulsion from hostel or mess and the like.

24.5. Unlawful activities: In case of students found involved in any unlawful activities either within or outside the Hostel/College Campus, besides, expulsion both from the Hostel and College at the discretion of the Dean, the matter will be reported to the Police of the jurisdiction to be dealt with, in accordance with the appropriate law in force.

25. RECOGNITION OF DOCTORAL TEACHERS

25.1. The Dean normally recognizes teachers for offering courses to the students of Doctoral programme based on the request of teachers and the recommendation of Head of the department.

25.2. The recognized Ph.D. teachers shall offer courses to Doctoral students as required by the concerned Heads of departments, normally, in their own field of specialization unless extra-ordinary circumstances demand for offering other courses.

25.3. **Teachers for Doctoral programme:** The following faculty shall be recognized as PG teachers for Doctoral programme

i. Professors
ii. Associate Professors
iii. Assistant Professors: Persons having a Doctoral degree with five years of active experience in the concerned field.

25.4. The Heads of departments will forward the proposals based on the qualification and experience of the teacher as given above. The proposals can be sent when there is acute need for teachers/guide in the prescribed format, given in the ***Annexure-6***.

25.5. While forwarding the application, the Head of the Department should consider the seniority of the teacher, number of courses handled and number of research schemes operated.

26. APPROVAL OF FINAL RESULTS, AWARD OF DEGREE AND ISSUE OF PROVISIONAL CERTIFICATES AND TRANSCRIPTS

26.1. Award of Degree:

i. The Degree will be awarded during Annual Convocation conducted by the University to candidates who have satisfactorily completed all the graduation requirements.
ii. The University shall issue a Provisional Degree Certificate to a candidate after having passed all provisional examinations.
iii. Date of completion of degree programme shall be the date of final viva-voce examination/ public defence.

26.2. Eligibility for the Award of the Degree: The successful completion of all the prescribed courses included in the Curricula and Syllabi shall be minimum requirement for the award of the Degree.

26.3. Percentage conversion: For obtaining the percentage equivalent to the OGPA, the OGPA secured by the student shall be multiplied by 10.

26.4. Transcript card:

i. The Transcript Card shall contain entry of all the courses and the Grade Points and OGPA obtained by the candidates indicating the number of times appeared. This will have to be prepared for all the students by the Controller of Examinations.

ii. For preparation of Transcript Card, the Dean should send recent passport size photograph of the students along with filled in proforma and the prescribed fee.

26.5. The Transfer Certificate and Conduct Certificate shall be issued by the Dean.

26.6. The Vice-Chancellor is empowered to withhold or cancel the Degree awarded when a mistake wilfully committed by the student is detected at a later date regarding the registration, OGPA and other requirements for successful completion of the degree programme.

26.7. Amending or Cancelling the Result: If it is established that the result of a candidate has been vitiated by malpractice, fraud or other improper conduct and that he/she has been a party to or connived at malpractice or improper conduct of another student, the Vice-Chancellor shall have the powers at any time to amend the results of such a candidate and to make such declaration as the Vice-Chancellor may deem necessary on that behalf including return of prize, scholarship money and debarring the candidate from the University for such periods as may be specified and to cancel the results of the candidate in such manner as the Vice-Chancellor may decide.

27. REMOVAL OF DIFFICULTIES:

27.1. If any difficulty arises in giving effect to the Provisions of these regulations, the Registrar/Dean may issue necessary orders which appear to him to be necessary or expedient for removing the difficulty.

27.2. Every order issued by the Registrar/Dean under this provision shall be laid before the Academic Council of the University immediately after the issuance.

27.3. Not-withstanding anything contained in the rules and regulations, the Board of Studies or Academic Council shall make changes whenever necessary.

DETAILS ON FEE TO BE PAID BY THE STUDENT
(Other than admission fee and semester fee)

Sl. No.	Particulars	Amount (Rs.)
1.	Late Registration fee	1000
2.	Re-registration fee with juniors	1000
3.	Duplicate hall ticket fee	200
4.	Fee for Transfer Certificate and Conduct Certificate	200
5.	Re-examination fee for comprehensive Qualifying Exam	5000
6.	Fee for availing grace period for submission of thesis a) Up to one month b) Up to three months	 1000 2500
7.	Penalty for failure to appear for public defence	5000
8.	Penalty for late submission of thesis after public defence	5000
9.	Examination fee (per course) *	
10.	Improvement/ Re-examination fee (per course) *	
11.	Fee for Provisional Degree Certificate *	
12.	Fee for Transcript Card *	
13.	Fee for Degree Certificate *	
14.	Fee for Migration Certificate *	

* As fixed by the University from time to time

28. REGULATIONS GOVERNED BY PAJANCOA & RI

28.1. FEE STRUCTURE

i) Fee structure is being revised every year with 10% fee hike. Lodging fees and charges for electricity, water and computer are revised based on the requirements and power tariff prevailing from time to time.

ii) In the case of new admissions, the fees for the first semester should be paid at the time of admission.

iii) For the remaining semesters, the fees should be paid on the date of registration of the semester.

iv) Candidates who discontinue after admission are not eligible for refund of fees except caution money deposit.

v) In case of a student who re-registers with junior batch, he/she has to pay the semester fees applicable to the junior batch in which he/she registers, besides the re-registration fee.

28.2. REGISTRATION

i) All newly admitted candidates should register during the first semester of the programme. A candidate admitted to the Doctoral programme should report to the Head of the Department concerned on the date of registration. It is the responsibility of the candidate to register the courses in person on the due date prescribed for the purpose.

ii) **In ABSENTIA** registration will not be permitted on any circumstances.

iii) The Head of the Department and the PG coordinator shall help the student in selecting the courses for registration.

iv) Admitted candidates shall register with the respective Department at the beginning of each semester and this should be completed within two working days.

28.2.1. Late registration:

a) Late registration is permitted by the Dean of college within seven working days from the commencement of the semester provided the prescribed late registration fee is paid before registration.

b) Registration beyond seven working days is not allowed except for new entrants who are admitted late due to administrative reasons in the first semester.

28.2.2. Registration cards:

i. A student shall register the courses offered in a semester by writing all the courses in registration card in quadruplicate. The format of registration card is given in *Annexure-4*.

ii. The Chairman, PG coordinator and Head of the Department are responsible to furnish the registration particulars of the students with their signature in the Registration card to the Dean.

iii. The Dean shall approve the registration cards.

iv. The approved registration cards shall be maintained by the Dean, PG coordinator, Chairman and the student concerned.

v. The list of courses registered by the students in each semester shall be sent by the Dean to the Controller of Examinations/University for preparation of Report Cards

28.2.3. The mess dues clearance certificate has to be produced by the student at the time of registration and examination.

28.3. QUALIFYING EXAMINATION

The Heads of departments will monitor and coordinate in conduct of both the written and oral qualifying examinations.

28.4. MERIT SCHOLARSHIP/RESEARCH ASSISTANTSHIP

i) PAJANCOA & RI fellowship shall be awarded to all the students who are admitted into the Ph.D programme based on allotment of Government fund. The students should be a resident of PAJANCOA & RI hostels. The award of fellowship is governed by the approved fellowship rules.

ii) The Dean shall call for applications and sanction the scholarship every year.

iii) The students availing any scholarship/fellowship are permitted to switch over to other fellowship/scholarship only one time during the course of study.

28.5. Student SRF:

i. The selection of student SRF in external funded schemes will be made by the existing committee members for selection of regular SRF.

ii. The PG coordinator of the concerned department will be an additional member of the committee.

iii. The panel of names after the selection has to be sent to the Dean for approval in the prescribed Proforma.

iv. If a student SRF/JRF discontinues before submitting the thesis or switch over to other fellowship/scholarship, the amount already paid has to be recovered in full in one lump sum with 6% penal interest.

28.6. GUIDELINES FOR HEADS OF THE DEPARTMENTS IN MONITORING PROGRESS OF DOCTORAL STUDENTS

28.6.1. Student records: The "Individual student" file (clip file) containing all the academic records of the student concerned with student's bio-data shall be maintained by the PG coordinator on behalf of the Institution. In each file a sheet containing the following information has to be attached.

i) Date of registration:
ii) Date of qualifying examination:
iii) Due date for thesis submission:
iv) Date of submission of thesis:
v) Date of viva-voce:
vi) Remarks:

28.6.2. The activities listed out in the following table must be meticulously taken care by the Professor and Head of the Department concerned

Sl. No.	Particulars	Time Schedule
1.	List of courses to be offered along with time table	A week before the commencement of each semester
2.	Course registration particulars	Within 10 working days from the date of commencement of each semester
3.	Mark lists after completing examinations	Within 10 days from the date of conduct of examinations

28.6.3. The time table for various examinations and evaluations of research credits should be prepared in advance as indicated in the academic calendar of semester concerned and such dates already fixed should not be postponed or changed subsequently.

28.6.4. The schedule for the important records to be sent to the Dean is furnished below and it should be followed strictly so as to get back the above academic reports in time for maintenance in the students file.

Sl. No.	Particulars	Time Schedule
1.	Formation of advisory committee **(Form 1)**	Within one month of the commencement of first semester
2.	Plan of course work **(Form 2)**	
3.	Programme of research work **(Form 3)**	Before the end of the semester in which the student registers the research credit for the first time or the commencement of the research work whichever is earlier.
4.	Proposal for qualifying examination **(Form 4)**	Two months before the completion of the course work.
5.	Qualifying examination result **(Form 5)**	The next day of the examination
6.	Panel of external examiners for	Three months before the probable date of

	thesis evaluation **(Form 6)**	submission of thesis
7.	Final viva-voce result **(Form 7)**	The next day of the examination
8.	Certificate for having carried out the suggestions of the external examiner and advisory committee (**Form 8**)	After receiving the evaluation report from the external examiner.

28.6.5. The Heads of the Departments should monitor the progress of the Doctoral students. Each department should maintain a list of thesis produced so far with the abstract of the same in both hard and soft copies.

Form – 1

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR FORMATION OF ADVISORY COMMITTEE

(To be sent in triplicate within one month from the commencement of First semester)

1. Name of the student :
2. Reg. No. :
3. Degree :
4. Subject :
5. Advisory committee :

S.No.	Advisory committee		Name, designation and department	Date of Retirement	Signature
1.	Chairperson	:			
2.	Co-Guide (If any)	:			
3.	Member	1.			
		2.			
		3.			
4.	Additional member	:			
5.	Reasons for additional member				

Signature of the student

PG coordinator **Head of the Department**

DEAN

* Additional members may be included only in the allied faculty related to thesis research with full justification at the time of sending proposals (Programme of research) to the Dean for approval.

Form – 1a

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR CHANGE IN ADVISORY COMMITTEE

(To be sent in triplicate)

1. Name of the student :

2. Reg. No. :

3. Degree :

4. Subject :

5. Proposed change :

	Name and designation	**Date of retirement**	**Signature**
a. Existing Chairperson/ Co-Guide/ member			
b. Proposed Chairperson/ Co-Guide member			

6. Reasons for change :

Signature of the student

Chairperson of the Advisory Committee **PG Coordinator**

Head of the Department **DEAN**

Form – 2

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR PLAN OF COURSE WORK

(To be sent in triplicate before 55th working day during the first semester)

1. Name of the student :

2. Reg. No. :

3. Degree :

4. Subject :

5. Course Programme :

S. No.	Course No	Course Title	Credit Hour
		Major courses	
		Minor courses	
		Supporting courses	
		Seminar	
		Research	
		TOTAL	

6. Tentative area of research : (indicate the major field of specialization)

Signature of the student

APPROVAL OF THE ADVISORY COMMITTEE

Advisory committee	Name	Signature
Chairperson		
Co-Guide (If any)		
Members	1.	
	2.	
	3.	

DEAN

Form – 3

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR PROGRAMME OF RESEARCH WORK

(To be sent in triplicate before the end of the semester in which the student registers research credit for the first time or the commencement of research work whichever is earlier)

1. Name :
2. Reg. No. :
3. Degree :
4. Subject :
5. Date of joining :
6. Title of the research project :
7. Objective(s) :
8. Duration :
9. Location (campus/station) :
10. Review of work done :

11. Broad outline of work/methodology:

12. Semester wise break up of work :

Signature of the student

APPROVAL OF THE ADVISORY COMMITTEE

Advisory committee	Name	Signature
Chairperson		
Co-Guide(If any)		
Members	1.	
	2.	
	3.	

DEAN

Form – 3a

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR CHANGE IN PROGRAMME OF RESEARCH

(To be sent in triplicate)

1. Name :

2. Reg. No. :

3. Degree :

4. Subject :

5. Reason for change :

6. Proposed change in the approved programme of research :

7. Number of credits completed so far under the approved programme :

8. a) Whether already earned credits are to be retained or to be deleted :

b) If retained, justification :

Signature of the student

APPROVAL OF THE ADVISORY COMMITTEE

Advisory committee	Name	Signature
Chairperson		
Co-Guide (If any)		
Members	1.	
	2.	
	3.	

DEAN

Form – 4

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR PROPOSAL OF QUALIFYING EXAMINATION

(To be sent in triplicate)

1. Name of the Department :
2. Degree :
3. Subject :
4. Whether all the courses have been completed :
5. Number of credits completed :
6. Whether the students have an OGPA of not less than 7.00/10.00 :
7. List of Ph.D. students appearing for qualifying examination :

Sl. No.	Name	I.D. No.	OGPA

8. Panel of External examiners :

Sl. No.	Name and Designation	Address	Area of specialization
1.			
2.			
3.			

9. Remarks :

PG coordinator **Head of the Department**

DEAN

Form – 5

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR COMMUNICATION OF RESULTS OF QUALIFYING EXAMINATION

(To be sent in triplicate)

1. Name of the student:

2. Reg. No.:

3. Degree:

4. Subject:

5. Date of examination:

6. Date of previous examination:
(only in case of re-examination)

7. Result (Successful/ Not successful*):
(*) to be written by the external examiner

EXAMINATION COMMITTEE

	Name in BLOCK letters	**Signature**
Chairperson		
Co-Guide (If any)		
Members	1.	
	2.	
	3.	
External Examiner		

Signature of Chairperson
with name and designation

PG Coordinator **Head of the Department**

DEAN

Form – 6

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR PROPOSAL OF EXTERNAL EXAMINERS FOR THESIS EVALUATION

(To be sent in duplicate in Confidential cover)

1. Name of the student :

2. Reg. No. :

3. Degree :

4. Subject :

5. Thesis title :

6. Name of the Chairperson :

7. Panel of external examiners* :

Sl. No.	Name and Designation	Address with Contact No. and Email	Area of specialization
1.			
2.			
3.			
4.			
5.			

*Five external examiners should be given

8. Remarks :

Signature of the Chairperson
of the advisory committee

DEAN

Form – 7

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR SENDING THE RESULT OF FINAL THESIS VIVA-VOCE EXAMINATION

(To be sent in duplicate)

1. Name of the student :
2. Reg. No. :
3. Degree :
4. Subject :
5. Thesis title as in final copy of the thesis :

6. Date and time of *viva-voce* :

7. Particulars of the External examiner(s) :
who has/have evaluated the thesis

Name and Designation of the External Examiner	**Remarks of the External Examiner**
1.	RECOMMENDED /RECOMMENDED FOR REVISION /NOT RECOMMENDED
2.	RECOMMENDED /RECOMMENDED FOR REVISION /NOT RECOMMENDED

8. **Recommendation of the Examining committee present at the time of final *viva voce* examination**:

a. Recommends/ does not recommend unanimously the award of degree

b. The performance of the candidate in final *viva voce* is assessed as _____ (very good/ good/ satisfactory/ not satisfactory)

Sl. No.	**Capacity of examiner**	**Name in BLOCK letters**	**Signature**
1.	Chairperson/Co-opted Chairperson*		
2.	Co-Guide		
3.	Member 1.		
	2.		
	3.		
4.	Additional member		
5.	External examiner		

* If co-opted in the absence of Chairperson/Member

The original report(s) from the external examiner(s) is/ are enclosed

Head of the Department

Chairperson of the Examining committee/ Advisory committee with designation

Form – 8

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

Certificate for having carried out the suggestions of the External Examiner and Advisory committee

(To be enclosed along with report of the public defense)

Certified that Thiru/Selvi/Tmt. _____

I.D. No. _____ has carried out all the corrections and suggestions as pointed out by the external examiners (s) and the advisory committee and has submitted _____ copies of his/her Ph.D. thesis in hard bound cover and CD's.

Signature of the Chairperson with Designation

Signature of the PG Coordinator

Signature of the Head of the Department

Approved By

DEAN

SEAL OF THE UNIVERSITY

Certificate Number:

Annexure – 1

PONDICHERRY UNIVERSITY
Puducherry – 605 014
Doctoral Degree Programme

REPORT CARD

Name	:		**Year of admission**	:	
Registration No.	:		**Semester**	:	
Father's Name	:		**Date of Registration**	:	
Date of birth	:		**Date of Start**	:	
College	:	Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal	**Date of Closure**	:	

Sl. No.	Course Code	Course Title	Credit Hours	Grade Point	Credit Points

E- Incomplete F- Fail S- Satisfactory NS-Not Satisfactory

Credit Status	Upto Last Semester		Current Semester		Cumulative Status	
	Credit Hours	Credit Points	Credit Hours	Credit Points	Credit Hours	Credit Points
Courses completed						
GPA/OGPA						

Prepared by	**Checked By**	**Asst. Registrar (Exams)**	**Controller of Examinations**

SEAL OF THE UNIVERSITY

Annexure – 2

Certificate Number:

PONDICHERRY UNIVERSITY, PUDUCHERRY – 605 014

TRANSCRIPT CARD

Name :
Register No :
Father's Name :
Mother's Name :
Date of Birth :
Month & Year of Admission :
Month & Year of Passing :

PHOTO

Name & Address of College : Pandit Jawaharlal Nehru College of Agriculture & Research Institute, Karaikal-609 603, U.T. of Pondicherry.

Name of University : Pondicherry University, R.V. Nagar, Kalapet, Puducherry 605014

Degree Programme : **Ph.D. ( )**

Semester	Course No.	Title of the Paper	Credit Hours T+P	Grade point Obtained	Session

Reg. no: **Name:**

*** Non Credit Courses** **S - Satisfactory**

Title of the Thesis	:	
Total Credit Hours	:	
Total Credit Points Obtained	:	
Overall Grade Point Average	:	
Percentage	:	
Class	:	
Viva – Voce Completed on	:	

Seal:
Date:

Signature of
CONTROLLER OF EXAMINATIONS

Classification of OGPA in 10.00 Point Scale.	
9.00 and above	First class with Distinction
8.00 to 8.99	First class
7.00 to 7.99	Second Class

Annexure – 3

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

STUDENT REGISTRATION CARD – Ph.D.

Name of the Student _____ Academic Year _____

Registration No. _____ Semester _____

Degree programme _____ Date of Registration _____

Year of Admission _____ Date of Commencement _____

COURSES REGISTERED

Sl. No.	Course Code	Course Title	Credit Hours	Remarks
		TOTAL CREDIT HOURS REGISTERED		

Signature of the Student	**Signature of the Chairperson**	**Signature of the Head of the Department**	**Coordinator of Examinations**

APPROVED BY

DEAN
PAJANCOA&RI
KARAIKAL

Annexure-4

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

LIST OF ENCLOSURES TO BE SUBMITTED ALONG WITH THESIS

A. At the time of sending thesis for External Evaluation:

1. One copy of abstract of thesis
2. One copy of the summary of research finding in English (within one page)
3. One copy of the summary of research finding in Tamil (within one page)
4. One page abstract of thesis with key words
5. Clearance certificate from Hostel
6. Clearance certificate from Library
7. Clearance certificate from Department
8. Clearance certificate from Staff advisor
9. Clearance certificate from Physical Education
10. Approved registration cards (One set)
11. Report cards (one set)
12. Course completion certificate (signed by Chairperson and HOD)
13. Attendance Certificate
14. Result of comprehensive qualifying examination
15. Permission and fee receipt for availing grace period, if any.
16. Certificate for Anti – Plagiarism (**Proforma 15**).
17. Two copies of paper bound thesis

B. At the time of submission after final viva-voce:

1. Report of the final thesis viva voce examination (To be sent in duplicate)
2. External Examiners thesis evaluation report (Two copies – original + Xerox)
3. Certificate for having carried out the suggestions of the external examiner and advisory committee
4. Thesis in hard bound copy – Four Numbers.
5. Soft copy the thesis in CD (cover to cover in PDF format) - Two Number.

Annexure-5

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROPOSAL FOR RECOGNITION OF TEACHERS FOR TEACHING/ GUIDING Ph.D. STUDENTS

1. Particulars of the teacher seeking recognition

a. Name of the teacher :
b. Date of birth of the teacher :
c. Designation & present official address of the teacher :
d. Date of joining service in the entry cadre :
e. Academic qualifications
Date of acquiring Bachelor's Degree :
Date of acquiring Master's Degree :
Date of acquiring Ph. D degree :
f. Total service as on the date of this proposal (excluding extraordinary leave) :
g. Date of retirement :

2. Recognition proposal submitted for (tick any one)

a. Recognition as teacher for Master's Programme
b. Recognition as Guide for Doctoral Programme

3. Teaching experience as on the date of Application

a. No. of UG courses offered :
c. No. of M.Sc courses offered :

Signature of the teacher with date

4. Particulars to be furnished by Head of the Department

No. of existing recognized teachers/guides pertaining to this proposal in your department :

Justification for additional requirement of teachers/guide :

Signature of the Head of Department

Approval of the Dean

Proforma – 1

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR REGISTRATION OF RESEARCH CREDITS

PART- A: PROGRAMME

Semester: Year: Date of registration:

1. Name of the student :

2. Reg. No. :

3. Total research credits completed so far :

4. Research credits registered during the semester :

5. Programme of work for this semester :

(list out the items of research work to be undertaken during the semester)

i)

ii)

iii)

iv)

APPROVAL OF THE ADVISORY COMMITTEE

Advisory committee	Name	Signature
Chairperson		
Members	1.	
	2.	
	3.	

(Approval may be accorded within 10 days of registration)

Proforma – 1

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR EVALUATION OF RESEARCH CREDITS

PART - B EVALUATION

(Evaluation to be done before the closure of semester)

Date of closure of semester :

Date of evaluation :

1. Whether the research work has been carried out as per the approved programme :

2. If there is deviation specify the reasons :

1. Performance * :

(*) Performance may be indicated as **SATISFACTORY /NOT SATISFACTORY**

APPROVAL OF THE ADVISORY COMMITTEE

Advisory committee	Name	Signature
Chairperson		
Members	1.	
	2.	
	3.	

Proforma-2

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PERMISSION FOR LATE REGISTRATION

1. Name of the student :
2. Reg. No. :
3. Degree :
4. Department :
5. Semester and Academic year :
6. Date of commencement :
7. Date of registration without fine :
8. Last date for registration with fine :
9. Date on which registration is sought :
10. Reason :
11. Signature of the student :
12. Remarks and recommendation of the Chairperson :

Signature of the Chairperson

PG Coordinator **Head of the Department**

DEAN

Proforma-3

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

WILLINGNESS TO BE GIVEN BY THE STUDENTS TO AVAIL FELLOWSHIP FROM EXTERNALLY FUNDED SCHEMES

1. Name of the student	:
2. Reg. No.	:
3. Degree	:
4. Subject	:
5. OGPA of Master degree	:
6. Name of the Chairperson	:
7. Discipline/Department	:
8. Thesis topic, if allotted	:
9. Current semester and year in which studying	:
10. Whether all the course works have been completed , if not indicate the pending courses with credit loads	:

Undertaking by the student:

i. I am willing to avail the proposed fellowship under the scheme entitled_____ _____.

ii. If I leave in the middle of the tenure of the fellowship, I am willing to repay the fellowship availed with 6% penal interest or any levy/fine imposed by the College/University.

I am willing to abide by all the rules and regulations laid down by the College/University in this regard.

Date: **Signature of Student**

Chairperson of the Advisory Committee **Head of the Department**

DEAN

Proforma-4

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

ALLOTMENT OF STUDENTS UNDER JRF/SRF STUDENT FELLOWSHIP

(To be submitted to the Dean)

1. Title of the scheme	:
2. Location of the scheme (Department)	:
3. Date of sanction of the scheme	:
4. Period of the scheme	:
5. Type of fellowship	: JRF/SRF
6. Period of fellowship (only for the period of research credits registered)	:
7. Amount of fellowship	: Rs……..p.m
8. Amount of contingent grant	: Rs……p.a.
9. Amount of T.A. provided	: Rs……..p.a.
10.a. Whether the technical programme submitted by the student to Dean is the same as envisaged in the scheme proposal	: Yes / No
b. If not, whether the revised programme of research is submitted (If yes, date of approval by the Dean)	:
11. No. of research credit(s) completed so far by the proposed fellowship awardees (student)	:
12. Whether the credits earned earlier are to be retained or to be cancelled?	:
13. Whether funds received	: Yes / No
14. Name of the student(s) & ID. No.	:
15. Number of semesters for which fellowship may be sanctioned	:
16. Can the fellowship be sanctioned for grace period also.	: Yes / No

Principal Investigator **Head of the Department** **Dean**

List of Enclosures

1. Copy of concurrence of the sponsor of the sponsor to avail student fellowship
2. Copy of administrative sanction by Dean
3. Student's willingness and undertaking

Proforma-5

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

SPONSOR'S CONCURRENCE (PROFORMA)

1. Title of the scheme :

2. Location of the scheme (Department) :

3. a. Name & Designation of the PI :

b. Name and designation of the Co-PI :

4. Type of fellowship : JRF/SRF

5. Period of fellowship :

a. Indicate the period of fellowship to be awarded :

b. Amount of fellowship : Rs……p.m.

c. Amount of contingent grant : Rs……p.a.

d. Amount of T.A. Provided : Rs……p.a.

e. Whether Institutional charges paid : Yes/No Rs……

Signature of the Sponsor

To

The DEAN,
PAJANCOA & RI,
Karaikal – 609 603.

Proforma-6

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

Proforma for Monitoring Register

Date of meeting	Review of the previous work that was assigned	Remarks of Chairperson	Work assigned for next week	Date on which the student has to report	Signature of the Student	Signature of the Chairperson

Proforma-7

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

Proforma for Obtaining Permission for Re-registration of credits

1. Name	:	
2. I.D No	:	
3. Department	:	
4. Campus	:	
5. Mention the current semester	:	Eg. III/IV/V etc.,
6. Re-registration is requested for the semester	:	IV/V/VI
7. Permission requested for re-registration of	:	
(a) Course credits	:	Second/Third time
(b) Seminar credits	:	Second/Third time
(c) Research credits	:	Second/Third/Fourth time

Grade Obtained E/NS/EE	**Reason for re-registration**	**Credit hours to be re-registered**

Signature of Student **Chairperson** **PG Coordinator**

Head of the Department

DEAN

Encl: The following document to be enclosed if re-registration is requested for

Note:

* Example: For Fourth time request: Permission order that was obtained for re-registering third time
* If temporary discontinuance was a reason, then Dean orders to be enclosed.
* For re-registering research credits for second time, the HoD may approve.

Proforma-8

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR EVALUATION OF CREDIT SEMINAR

1. Name of the Student :
2. Register No :
3. Semester & Academic Year :
4. Seminar Title :

Sl. No.	Description	Max. Marks	Marks Awarded
1.	Synopsis of the Seminar	10.00	
2.	Presentation		
	a) Introduction	05.00	
	b) Style Clarity	10.00	
	c) Sequence and Organization	05.00	
	d) Topic Coverage	20.00	
	e) Effective use of Audio Visual Aids	05.00	
	f) Time Management	05.00	
	g) Response to Question during discussion	10.00	
3.	Report	30.00	
	TOTAL	**100**	

Grade: _____

Date: **Signature**

Proforma-9

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

DEPARTMENT OF _____

COURSE COMPLETION CERTIFICATE

This is to certify that Thiru./Selvi/Tmt._____ Reg. No._____ has completed all the course and research credit requirements on _____ for the award of Ph.D. (Agri./Horti.) degree in_____.

Professor and Head

Signature of the Chairperson
(with Name and designation)

Proforma-10

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

JUSTIFICATION FOR LATE SUBMISSION OF THESIS (if applicable)

1. Name of the student :

2. Reg. No. :

3. Degree :

4. Subject :

5. Date of first registration for the degree :

6. Number of semesters for which the candidate could not register :

7. Reason for not registering and continuing the study :

8. Period of delay in submission of thesis :

9. Period lost due to transfer/ill health :

10. Date of submission of thesis :

Signature of the student

11. Specific remarks and recommendation of: the Chairperson

Signature of the Chairperson with designation

12. Specific remarks and recommendation of: the Head of department

Signature of the Head of the Department

13. Approval of the Dean :

Signature of the Dean

Profroma-11

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR EVALUATION OF THESIS

Name of the degree programme: Ph.D. (Agri) in _____.

1. Name and Designation of the examiner :

2. Address of the Examiner:

Telephone/Mobile:

Fax:

E-mail:

3. Name of the candidate:

4. Reg. No.:

5. Title of the thesis:

6. Date of receipt of the thesis copy:

7. Date of despatch of the detailed report and:
thesis by the examiner to the Dean

8. Examiner's recommendations choosing one:
of the following based on quality of thesis

a. Recommended for award
b. Recommended for revision

9. Please state whether a list of questions if:
any to be asked at the viva-voce
examination (Questions to be attached)

Date: **Signature of the Examiner**
Official Seal:

Note: Please enclose a detailed report in duplicate duly signed by you giving the merits and demerits of the thesis on the choice of problem, review of literature, methods followed, results and discussion etc.

Proforma-12

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

DEPARTMENT OF _____

CERTIFICATE FOR HAVING CARRIED OUT THE SUGGESTIONS OF THE EXTERNAL EXAMINER AND ADVISORY COMMITTEE

(To be enclosed along with result of the final viva voce examination)

Certified that Thiru./Selvi./Tmt_____

Reg. No. _____ has carried out all the corrections and suggestions as pointed out by the external examiners(s) and the advisory committee and has submitted **FOUR** copies of his/her Ph.D. thesis in hard bound cover and **TWO** soft copies of thesis in PDF format in CDs.

Head of the Department

Signature of the Chairperson with Name and designation

Proforma-13

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

PROFORMA FOR OBTAINING PERMISSION TO PRESENT PAPERS IN SEMINAR/ SYMPOSIA/ TRAINING

(To be sent in triplicate)

1. Name of the student :
2. Reg. No. :
3. Department & College :
4. Name of the Chairperson with designation :
5. Whether course work has been completed?
6. Title of paper/poster to be presented (enclose copy) :
7. a. Name of the seminar/symposium :
   b. Venue :
   c. Dates (From-To) :
8. Period of absence (in days) inclusive of travel time :
9. Whether the paper was sent through proper channel (copy to be enclosed) :
10. Cost of travel & registration fee borne By the student himself (or) supported by the scheme in which he is drawing fellowship? :

Date: Signature of the Student

Specific Recommendations:

Chairperson Professor and Head

PERMISSION TO ATTEND THE SEMINAR/ SYMPOSIA

(to be issued by the Dean)

1. Permitted without any financial commitment to the College/ University / **Not permitted**
2. Period of absence from_____ to _____(_____ days) is to be treated as duty and can be counted for attendance.
3. Period of absence from _____to _____(_____days) **is not treated as duty and cannot be counted for attendance.**
4. The student should submit a report to the Dean, within 3 days after his return.

DEAN

Proforma-14

PONDICHERRY UNIVERSITY

PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

APPLICATION FOR ISSUE OF CONDUCT AND TRANSFER CERTIFICATES

(To be submitted by the student with the recommendation of the Chairperson/ Head)

1. Name of the student :
2. Reg. No. :
3. Name of the Chairperson :
4. Designation of the Chairperson :
5. Name of the course undergone :
6. Year of joining course :
7. Year of leaving the course :
8. Whether copy of the PC enclosed :
9. Whether original clearance certificate from warden enclosed :

Date: **Signature of the Student**

Recommendations:

Certified that the conduct and characters of Mr/Ms._____ were_____ during the period of his/her studies. The certificates may be issued accordingly.

Chairperson **PG Co-ordinator** **Professor & Head**

Proforma-15

PONDICHERRY UNIVERSITY
PANDIT JAWAHARLAL NEHRU COLLEGE OF AGRICULTURE AND RESEARCH INSTITUTE, KARAIKAL – 609 603

Proforma for Plagiarism Check

1	Name of the Student	
2	ID Number	
3	Degree	Doctoral
4	Title of the Thesis	
5	Department Name	
6	Campus	
7	Name of the Chairperson	
8	Total Word Count in the Document	
9	Initial Submission If No, If more than 5 times of submission,	Yes / No Provide the number of times plagiarism checked along with their plagiarism percent Provide the details of fine paid
10	Date of Submission	
11	Self-Plagiarism Exclusion D etails (if published)	Kindly provide the links of your own publication (URL / DOI) to be excluded 1. 2.

Signature of the Student

Chairman / PG Coordinator / Head of the Department

Curricula and Syllabus

Doctor of Philosophy (Ph.D.)

COURSE CURRICULA AND SYLLABI

DESCRIPTION OF TERMINOLOGIES

Major Course	The subject of Department or discipline in which the student takes admission. Among the listed courses, the core courses compulsorily to be registered shall be given '*' mark
Minor Course	The course closely related to a student's major subject
Supporting Course	The course not related to the major course. It could be any course considered relevant for student's research work or necessary for building his/her overall competence

Credit Requirements

	Particulars	Credits
(i)	**Course Work**	
	Major courses	12
	Minor courses	06
	Supporting courses	05
	Seminar (2 number)	02
(ii)	**Thesis Research**	75
	TOTAL	**100**

SUPPORTING COURSES

Sl No.	Course Code	Course Title	Credits
01	MAT 601	Advanced Operations Research	2+1
02	STA 601	Applied Regression Analysis	2+1
03	STA 602	Multivariate Analysis for Applied Sciences	1+1
04	COM 601	Programming with R	1+1

MAT 601 Advanced Operations Research 2+1

Aim of the course

To provide an in depth knowledge in formulation of non -linear programming problems, integer programming, and Quadratic Programming. The application problems can be solved by using software packages.

Theory

Unit I

Formulating a nonlinear programming problem – unconstrained and constrained optimization problems – equality constraints - Lagrangian Multipliers-Hessian and bordered Hessian Matrices inequality constraints – Kuhn Tucker conditions.

Unit II

Linear programming -Definitions of primal and dual problems-Duality theorems, Complementary Slackness Theorem-Dual Simplex method – Economic interpolation of duality-Post-Optimal Analysis. Post-optimality Analysis-Changes in the objective function coefficients- Post-optimality Analysis Changes in the bi values- Post-optimality Analysis-Changes in the coefficients aij's.

Unit III

Integer programming problems - Gomary's Cutting Plan method - Quadratic programming – Wolfe's modified simplex method- Beale's method. Goal programming problem – Formation and Algorithm- The weights method -The preemptive method

Unit IV

Markov Chains- Definition- Transition probability Matrices – Calculation of n step transition probabilities – Steady state conditions. Simulation – definition – Simulation models –generation of random numbers -Monte Carlo simulation – Application of simulation in queuing systems, maintenance problems, investment and budgeting.

Unit V

Dynamic programming problem- Formulation – Forward and backward, recursive methods- Discrete Dynamic Programming- Continuous Dynamic Programming. Software Packages for solving Operational Research problems

using MS Excel Solver, TORA, R, MATLAB, and other software packages.

Practical

Formulating a nonlinear programming problem - Problems in unconstrained and constrained optimization. Equality and inequality constraints - Kuhn Tucker conditions. Problems in Dual Simplex method – Economic interpolation of duality - Integer programming problems – Gomary's cutting plan method - Problems in quadratic programming, geometric programming– Dynamic programming – Forward and backward recursive methods. Markov decision problem. Transition probabilities – Transition matrices – n step transition probabilities – Steady state conditions – Simulation – definition – Simulation models - Monte Carlo simulation – generating random observations from uniform, exponential and normal probability distributions. Hands on sessions in MS Excel solver – GAMS – MATLAB and other software packages.

Learning Outcome

The students can acquire in depth knowledge in constrained and unconstrained optimization techniques. Also they obtain knowledge in linear and non-linear programming problems and they can solve the problems using software

Lecture Schedule

1. Formulating a non linear programming problem
2. Unconstrained optimization problems –functions of single variables
3. Unconstrained optimization problems –functions of several variables- Hessian Matrices
4. Constrained Optimization-Equality constraints –Lagrangian multipliers-Bordered Hessian matrices
5. Constrained Optimization –Inequality constraints with inequality constraints - Kuhn Tucker conditions
6. Linear programming – Definition of primal and dual
7. Duality theorems, Complementary Slackness Theorem
8. Dual simplex method
9. Economic interpolation of duality
10. Post-optimality Analysis-Changes in the objective function coefficients
11. Post-optimality Analysis-Changes in the **bi** values
12. Post-optimality Analysis-Changes in the coefficients **aij's**.
13. Integer programming problems -
14. Gomary's Cutting Plan method
15. Quadratic programming – Wolfe's modified simplex method
16. Quadratic programming – Beale's method.
17. Goal programming problem – Formation and Algorithm
18. The weights method
19. The preemptive method
20. Markov Chains – Definition - Transition probabilities
21. Calculation of n step transition probabilities and Steady State probabilities
22. Simulation definition – Simulation Models – Generation of Random numbers
23. Monte Carlo simulation

24. Application of simulation in queuing and inventory problems.
25. Application of simulation in maintenance and budgeting problems
26. Dynamic programming problem- Formulation – Forward and backward recursive methods
27. Discrete Dynamic Programming
28. Continuous Dynamic Programming
29. Stochastic Programming Problems.
30. Use of MS Excel solver in solving Optimization problems.
31. MATLAB ,GAMS and its features
32. MATLAB ,GAMS and its features
33. Features of other packages in solving OR problems

Practical Schedule

1. Unconstrained optimization problems –functions of single variables
2. Unconstrained optimization problems –functions several variables
3. Problems in Constrained Optimization-Equality constraints
4. Constrained Optimization –Inequality constraints with inequality constraints - Kuhn Tucker conditions
5. Problems in Dual simplex method
6. Integer programming problems - Gomary's cutting plan method
7. Quadratic programming Problems
8. Goal programming formation and solution
9. Discrete Dynamic programming problems
10. Continuous Dynamic programming problems
11. Markov chain-Construction of transition matrices - computation and steady state Proabilities
12. Simulation models- Monte Carlo simulation
13. Simulation in queuing and inventory problems
14. Simulation in maintenance and budgeting problems
15. Solving Use of MS Excel solver
16. Solution by GAMS and MATLAB
17. **Final practical examination**

1. Fryer MJ and Greenman JV(1987)- Optimisation Theory Applications in OR and Economics, Edward Arnold, London
2. Hamdy A. Taha (2002) -Operations Research (seventh edition) Prentice Hall of India Publisher, New Delhi.
3. MJ. Fryer and JV Greenman (1987) Optimization Theory: Applications in OR and Economics, Edward Arnold
4. Kanti Swarup, P.K Gupta, Man Mohan (1988) Operations Research (latest Edition) Sultan Chand & Sons educational publisher, New Delhi (latest edition).
5. Michael D. Intriligator (1971), Mathematical Optimization and Economic Theory, Prentice- Hall of India Pvt Ltd., New Delhi

6. Don.T Phillips, Ravindran A. and James J.Solberg 1986 - Operations Research Principles and Practice

Suggested websites

1. http://en.wikipedia.org/wiki/Queueing_model
2. http://en.wikipedia.org/wiki/Dynamic_programming

STA 601 Applied Regression Analysis 2+1

Aim of the Course

To get depth knowledge and understanding of the linear and non-linear regression model and its limitations.

To learn how to develop regression model and check regression diagnostics and apply for the specific perspective data.

Theory

Unit I: Correlation Analysis

Introduction to correlation analysis and its measures, Rank correlation, Testing of population correlation coefficients; Multiple and partial correlation coefficients and their testing.

Unit II: Regression Diagnostics

Problem of correlated errors; Auto correlation; Heteroscedastic models, Durbin Watson Statistics; Removal of auto correlation by transformation; Analysis of collinear data; Detection and correction of multi collinearity

Unit III: Regression analysis

Assumption and properties of regression coefficient - Method of least squares for curve fitting; Testing of regression coefficients and intercept. Coefficient of determination

Unit IV: Multiple Regression Analysis

Multiple and partial regressions - Diagnostic of multiple regression equation; Concept of weighted least squares; Various methods of selecting the best regression equation – Forward selection method, Backward elimination method, Stepwise regression

Unit V: Nonlinear Regression Analysis

Concept of nonlinear regression and fitting of quadratic, exponential and power curves; Economic and optimal dose, Orthogonal polynomial

Practical

Correlation coefficient and test of significance, Rank correlation. Regression analysis - Method of least squares for curve fitting - testing of hypothesis residuals and their applications in outlier detection; Handling of correlated errors, multi collinearity; - Multiple and partial regressions - Diagnostic of multiple regression equation Fitting of quadratic, exponential and power curves, fitting of orthogonal polynomials

Learning Outcome

After completion of this course the students will be able to

- Identify the relationship between the variables and solve problems involving simple and multiple linear regression.
- Select the best regression model and variables contributing to model.
- Carry out regression analysis for given data using different diagnostic measures, transformation.
- Fit linear and Non-linear regression curves and its implementation in real life situation

Lecture Schedule

1. Introduction to correlation analysis and its measures
2. Assumption and properties of correlation coefficient
3. Rank correlation
4. Testing of population correlation coefficients
5. Multiple correlation coefficients and their testing
6. Partial correlation coefficients and their testing
7. Correlation ratio
8. Auto correlation
9. Biserial correlation
10. Problem of correlated errors
11. Removal of auto correlation by transformation
12. Analysis of collinear data
13. Detection of multi collinearity and remedies
14. Correction of multi collinearity
15. Heteroscedastic models
16. Durbin Watson Statistics
17. Introduction to Regression analysis
18. Assumption and properties of regression coefficient
19. Method of least squares for curve fitting
20. Testing of regression coefficients
21. Interpretation of regression coefficient and intercept
22. Partial regressions
23. Multiple regression equation
24. Diagnostic of multiple regression equation
25. Concept of weighted least squares
26. Various methods of selecting the best regression equation - Forward selection method, Backward elimination method
27. Various methods of selecting the best regression equation - Stepwise regression
28. Concept of nonlinear regression
29. Fitting of quadratic curves
30. Fitting of exponential curves
31. Fitting of power curves
32. Economic and optimal dose
33. Orthogonal polynomial

Practical Schedule

1. Calculation of correlation coefficient

2. Calculation of partial correlation coefficient
3. Fitting of multiple linear regression equation
4. Testing of multiple linear regression coefficients
5. Calculation of Residuals and checking assumption of residuals
6. Outlier detection using residuals
7. Handling of correlated errors
8. Detection on multi-collinearity
9. Dealing with multi-collinearity
10. Detection on Autocorrelation
11. Detection on Heteroscedasticity
12. Estimation of linear model
13. Fitting of quadratic curves
14. Fitting of exponential curves
15. Fitting of power curves
16. Fitting of orthogonal polynomials
17. **Final practical examination**

Suggested Readings

1. David G. Kleinbaum, Lawrence L. Kupper, AzharNizam (2007). Applied Regression Analysis and Other Multivariable Methods (Duxbury Applied) 4th Ed.

2. Draper NR and Smith H. 1998. Applied Regression Analysis. 3 Ed. John Wiley.

3. Ezekiel M. 1963. Methods of Correlation and Regression Analysis. John Wiley

4. Kleinbaum DG, Kupper LL, Muller KE and Nizam A. 1998. Applied Regression Analysis and Multivariable Methods. Duxbury Press

5. Koutsoyiannis A. 1978. Theory of Econometrics. MacMillan

6. Kutner MH, Nachtsheim CJ and Neter J. 2004. Applied Linear Regression Models. 4th Ed. With Student CD. McGraw Hill

7. Chatterjee S, Hadi A and Price B.1999. Regression Analysis by Examples. John Wiley

8. Draper NR and Smith H. 1998. Applied Regression Analysis. 3rd Ed. John Wiley

9. David G. Kleinbaum, Lawrence L. Kupper, AzharNizam (2007). Applied Regression Analysis and Other Multivariable Methods (Duxbury Applied) 4th Ed

10. Draper NR and Smith H. 1998. Applied Regression Analysis. 3 Ed. John Wiley.

Suggested Websites

1. https://en.wikipedia.org/wiki/Regression_analysis
2. http://home.iitk.ac.in/~shalab/course5.htm

STA 602 Multivariate Analysis for Applied Sciences 1+1

Aim of the Course

- To learn and develop scientific view to deal with multidimensional datasets and its uses in the analysis of research data.

To understand the extensions of univariate techniques to multivariate frameworks and learn to apply dimension reduction techniques used in the data analysis.

Theory

Unit I: Multiple Regression Analysis

Multivariate statistical techniques – multiple linear regression – full model – stepwise regression –Step–up and step–down regression. Logit and Probit regression – two stage least squares –Canonical correlation.

Unit II: Principal Component and Factor Analysis

Principal component analysis – extraction of principal component – interpretation and uses – factor analysis – nature of factor analysis – basic concepts – assumptions of factor analysis – factor loadings – calculated rotated values – communalities – varimax rotation – quartimax rotation orthomax rotation

Unit III: Discriminant Function and Cluster Analysis

Discriminant function analysis – simple and multiple discriminant analysis – selection of variables – Cluster analysis – purpose of cluster analysis – hierarchical clustering – k means clustering dendrogram – interpretation of dendrogram.

Unit IV: Multi-Dimensional Scaling

Multi-dimensional scaling – method – metric and non–metric – interpretation.

Unit V: Reliability aned Path Analysis

Reliability analysis – methods – split half method – Cronbach's Alpha – path analysis – path coefficients – direct and indirect effects – path diagram.

Practicals

Multivariate statistical techniques - Full model regression equation - fitting using software - analysis and interpretation. Stepwise regression analysis - Step up method, Step–down method – Stepwise regression analysis using software. Computation of Logit regression equation - two stage least square regression equation - Canonical correlation. Principal components analysis – deriving the components and its interpretation. Factor analysis - with varimax rotation - quartimax and other rotations. Discriminant analysis - simple discriminant analysis - Multiple discriminant analysis. Cluster analysis -k-means method - hierarchical clustering method and dendrogram. Multi- dimensional analysis - Split half method of reliability - Kornbach's Alpha. Path analysis.

Learning Outcome

After completion of this course the students will be able to

- Carry out an extensive exploratory multivariate analysis for a given multivariate

data.

- Interpret statistically the multivariate data through the various multivariate techniques.
- Carry out classification of given multivariate data.
- Solve problems involving multivariate normal distribution and to do good research in agricultural data.

Lecture Schedule

1. Multivariate techniques – introduction and basics – use of SYSTAT software
2. Full model regression equations – selection of variables – fitting – analysis and interpretation
3. Stepwise regression analysis – step up method
4. Stepwise regression analysis – step down method
5. Logit regression equation fitting and interpretation
6. Probit regression equation – fitting and interpretation
7. . Canonical correlations – computation and interpretation
8. Principal component analysis – deriving the components and its interpretation
9. Factor analysis – objective – designing and assumptions – various rotations
10. Deriving factors and assessment of overall fit – interpreting the factors
11. Discriminant analysis – classification of multivariate observations – principles – simple discriminant analysis – equation fitting
12. Multiple discriminant analysis – equation fitting
13. Cluster analysis – principles – steps in clustering – k – means method – hierarchical clustering method – dendrogram – interpreting the dendrogram
14. Multi dimensional analysis technique – method and interpretation
15. Reliability analysis – methods – split half method – Cronbach's Alpha
16. Path analysis – path coefficients – direct and indirect effects – construction of path diagram

Practical Schedule

1. Full model regression equations – fitting using software – analysis and interpretation
2. Stepwise regression analysis – step up method using software
3. Stepwise regression analysis – step down method using software
4. Computation of Logit regression equation
5. Computation of two stage least square regression equation
6. Computation of Canonical correlation
7. Principal components analysis – deriving the components and its interpretation
8. Factor analysis – with varimax rotation
9. Factor analysis – quartimax and other rotations
10. Discriminant analysis – simple discriminant analysis
11. Multiple discriminant analysis
12. Cluster analysis – k–means method
13. Cluster analysis – hierarchical clustering method and dendrogram
14. Multi dimensional analysis
15. Split half method of reliability – Kornbach's Alpha
16. Path analysis
17. **Final practical examination**

Suggested Readings

1. Anderson TW. 1984. An Introduction to Multivariate Statistical Analysis. 2nd Ed. John Wiley
2. Arnold SF. 1981. The Theory of Linear Models and Multivariate Analysis. John Wiley
3. Giri NC. 1977. Multivariate Statistical Inference. Academic Press
4. Johnson RA and Wichern DW. 1988. Applied Multivariate Statistical Analysis. Prentice Hall
5. Kshirsagar AM. 1972. Multivariate Analysis. Marcel Dekker.
6. Muirhead RJ. 1982. Aspects of Multivariate Statistical Theory. John Wiley.
7. Rao CR. 1973. Linear Statistical Inference and its Applications. 2nd Ed. John Wiley
8. Rencher AC. 2002. Methods of Multivariate Analysis. 2nd Ed. John Wiley
9. Srivastava MS and Khatri CG. 1979. An Introduction to Multivariate Statistics. North Holland

Suggested Websites

1. https://en.wikipedia.org/wiki/Multivariate_statistics
2. https://online.stat.psu.edu/stat505/
3. https://www.iiap.res.in/astrostat/School08/PennStateSchool08_LecNotes.pdf
4. https://www.math.uci.edu/~htucker/LectureNotes/MultivariateAnalysis.PDF
5. http://i2pc.es/coss/Docencia/ADAM/Notes/MultivariateAnalysisSlides.pdf
6. http://www.statslab.cam.ac.uk/~pat/AppMultNotes.pdf

COM 601 Programming with R 1+1

Aim of the Course

To give an idea about programming in R software and learn how to use R for data visualization

Theory

Unit I

R Console; R Data types; R Vector creation using c(); R Assignment operators = <- ; R Arithmetic Operators; R Logical Operators; R Relational Operators;

Unit II

R Matrix- Create, Print, Add Column using cbind(), Add Row using rbind(), Slice using [,]; R Data Frame - Create using data.frame(), Edit using edit(), Append using cbind(), rbind(), select(), subset(), sort using order(); List in R - Create using list(), Select; Data Importing and Exporting in R Using read.table() and write.table();

Unit III

Install.packages(), library(); Introduction to Machine Learning; Introduction to R package tensorflow Introduction to R package keras.

Unit IV

Rscript If, Else, Else If statements in R; For Loop and While Loop in R; R user defined Functions

Unit V

Scatter Plot, Bar Chart and Histogram in R; Data Visualization with R ggplot2; Publishing Data Visualizations with R Shiny;

Practical

R Console; R Vector creation using c(); R Assignment operators = <- ; R Matrix- Create, Print, Add Column using cbind(), Add Row using rbind(), Slice using [,]; R Data Frame - Create using data.frame(), Edit using edit(), Append using cbind(), rbind(), select(), subset(), sort using order(); List in R - Create using list(), Select; Data Importing and Exporting in R Using read.table() and write.table(); install.packages(), library(); install.packages("tensorflow"); install.packages("keras"); Rscript, If, Else, Else If statements in R; For Loop and While Loop in R; R user defined Functions; Scatter Plot, Bar Chart and Histogram in R; Data Visualization with R ggplot2; Publishing Data Visualizations with R Shiny;

Learning Outcome

The course will impart knowledge on how to analyze and visualize data using R programming

Lecture schedule

1. R Console; R Data types; R Vector creation using c(); R Assignment operators = <-
2. R Arithmetic Operators; R Logical Operators; R Relational Operators;

3. R Matrix- Create, Print, Add Column using cbind(), Add Row using rbind(), Slice using [,];
4. R Data Frame - Create using data.frame(), Edit using edit(), Append using cbind(), rbind(), select(), subset(), sort using order();
5. List in R - Create using list(), Select; Data Importing and Exporting in R Using read.table() and write.table();
6. Install.packages(), library();
7. Install.packages("tensorflow");
8. Install.packages("keras");
9. Rscript
10. If, Else, Else If statements in R;
11. For Loop in R;
12. While Loop in R;
13. R user defined Functions
14. Scatter Plot, Bar Chart and Histogram in R;
15. Data Visualization with R ggplot2;
16. Publishing Data Visualizations with R Shiny;

Practical Schedule

1. R Console; R Vector creation using c(); R Assignment operators = <- ;
2. R Matrix- Create, Print, Add Column using cbind(),
3. Add Row using rbind(), Slice using [,];
4. R Data Frame - Create using data.frame(), Edit using edit(), Append using cbind(), rbind(), select(), subset(), sort using order();
5. List in R - Create using list(), Select; Data Importing and Exporting in R Using read.table() and write.table();
6. Install.packages(), library();
7. Install.packages("tensorflow");
8. Install.packages("keras");
9. Rscript
10. If, Else, Else If statements in R;
11. For Loop in R;
12. While Loop in R;
13. R user defined Functions;
14. Scatter Plot, Bar Chart and Histogram in R;
15. Data Visualization with R ggplot2;
16. Publishing Data Visualizations with R Shiny;
17. **Final Practical Examination**

Suggested Readings

1. Michael J. Crawley (2013). The R Book. 2nd Edition. John Wiley
2. Robert Gentleman (2008). R Programming For Bioinformatics. Chapman and Hall/CRC.
3. Brian S. Everitt and Torsten Hothorn (2009). A Handbook of Statistical Analyses Using R. Second Edition. Chapman and Hall/CRC

Suggested Websites

1. RStudio.com Shiny Tutorial - https://shiny.rstudio.com/tutorial/ - https://shiny.rstudio.com/articles/
2. R Interface to Tensorflow - https://tensorflow.rstudio.com/
3. R Interface to Keras - https://keras.rstudio.com/

Ph.D
Agricultural Economics

Ph.D. Agricultural Economics

Sl No.	Course code	Course Title	Cr. Hr.
I.	**Major courses (12 credits)**		
01	AEC 601*	Advanced Micro-Economic Analysis	1+1
02	AEC 602*	Advanced Macro-Economic Analysis	2+0
03	AEC 603*	Advanced Applied Econometrics	2+1
04	AEC 604*	Advanced Production Economics	2+1
05	RPE 601*	Research and Publication Ethics	2+0
II.	**Minor Courses (6 credits)**		
01.	AEC 605	Advanced Agricultural Marketing and Price Analysis	1+1
02.	AEC 606	Quantitative Development Policy Analysis	1+1
03.	AEC 607	Advanced Natural Resource Economics	1+1
04.	AEC 608	Environmental Economics	1+1
05.	AEC 609	International Trade Theories and Policy Applications	1+1
III.	**Supporting Courses (5 credits)**		
IV.	**Seminar (2 credits)**		
01	AEC 691	Doctoral Seminar	0+1
02	AEC 692	Doctoral Seminar	0+1
V.	**Thesis Research (75 credits)**		
01	AEC 699	Doctoral Research	0+75

* Courses to be compulsorily registered

MAJOR COURSES

AEC 601*	ADVANCED MICRO ECONOMIC ANALYSIS	1+1

WHY THIS COURSE?

This Course enables the students to enrich the width and depth of their Knowledge horizon with respect to Micro-Economics**.** Further, the students would have an integrated view of the body of microeconomics and its relevance for economic policy, and have a working knowledge of the main analytical methods used to study micro economic problems.

OBJECTIVE

The main objective is to make the students comfortable with the models and arguments that the professional literature uses to describe and prescribe policy. In an effort to meet this goal, more focus would be on problem solving approach with practical application. Topics covered include an advanced treatment of consumer theory including duality in consumer theory, demand systems, and comparative static analysis; competitive market equilibrium; externalities and public goods; asymmetric information; and general equilibrium, welfare economics and social choice. In nutshell, this course presents key concepts from microeconomic theory at high level of

abstraction – with an eye to policy analysis.

THEORY

Unit I: Consumer Theory

Theory of consumer behaviour – Duality in consumer theory - expenditure function and indirect utility function - Measurement of Income Effect and Substitution Effect. Measurement of Changes in Consumers' Welfare – Consumer's Surplus, Compensating Variation and Equivalent Variation - Dynamic versions of demand functions – Integrability of demand functions. Demand Models – Linear Expenditure System and Almost Ideal Demand System. Applications of consumer theory –Household model and time allocation – Labour supply decisions by households.

Unit II: Market

Advanced treatment of Perfect competition – Monopoly, Monopolistic Competition and Oligopoly. Oligopoly models –Collusive and Non-collusive models of Oligopoly - Cournot solution, Bertrand's Duopoly Model, Chamberlin model, Stackleberg solution – Kinked Demand Curve.

Unit III: General Equilibrium

General Equilibrium Theory - Conditions and Concepts -Mathematical derivations of conditions of General Equilibrium - General equilibrium with Production and Consumption. Walras' Law - Existence, Uniqueness and Stability of general competitive equilibrium - Walrasian general equilibrium.

Unit IV: Market Failure	
Market failure - Incomplete markets - Asymmetric information – Principal - Agent problem – Adverse selection - Moral hazard. Externalities – Network externalities - Public goods – Optimal provision of public goods.	
Unit V: Welfare Economics	
Welfare Economics - Concepts, Problems, Approaches and Limitations of Welfare Economics, Pareto conditions of maximum welfare – Criteria for Social Welfare - Social Welfare functions, Social versus Private costs and benefits – Public Choice - Arrow's Impossibility Theorem.	
PRACTICALS	
Problems in consumer utility maximization – Estimation of income and substitution effects; Estimation of Consumer's surplus, equivalent variation and compensating variation. Estimation of demand models – Derivation and estimation of labour supply equations from household models. Comparative static analysis in consumption. Advanced problem solving in price determination under perfect competition, monopoly, oligopoly and monopolistic competition. Problems solving in General Equilibrium Theory and Welfare Economics. Problems in public goods provision.	
LECTURE SCHEDULE	
1	Theory of consumer behaviour – utility maximization – Derivation of demand function - Expenditure function and Indirect utility function. Duality in consumer theory – Roy's identity, Shephard's Lemma, Composite Commodity Theorem
2	Demand Decomposition – Hicks and Slutsky Decomposition - Income Effect and Substitution Effect. Measurement of Changes in Consumers' Welfare – Consumer's Surplus, Compensating Variation and EquivalentVariation
3	Comparative static analysis of changes in demand for commodities due to changes in prices and income. Integrability of demand functions
4	Dynamic versions of demand functions. Demand Models – Linear Expenditure System, Almost Ideal Demand System
5	Applications of consumer theory - Time allocation and household model – Labour-leisure model – Labour supply decisions of households
6	Price determination under perfect competition and monopoly – Price Discrimination - Measurement of welfare effects using comparative static analysis.
7	Oligopoly - Cournot solution, Bertrand's Duopoly Model, Chamberlin model and Stackleberg solution. Kinked Demand Curve – Equilibrium under Monopolistic Competition
8	Market failure - Incomplete markets - Externality problem – Network externality
9	Theory of Public goods – Optimal provision of pure and impure public goods.
10	Asymmetric information – Principal - Agent problem and Moral hazard.

11	General Equilibrium Theory - Conditions and Concepts, General equilibrium with Production and Consumption
12	Market equilibrium - Existence, Uniqueness, Stability of the market equilibrium. Walrasian general equilibrium model
13	General competitive equilibrium - definitions, Fixed-point theorem, existence, uniqueness and stability of general competitive equilibrium
14	Welfare Economics - Concepts, Problems, approaches and limitations of Welfare Economics
15	Pareto conditions of maximum welfare, Edgeworth box approach, Social Welfare functions – Sen's approach to social welfare
16	Applications of welfare economics – welfare effects of policies
PRACTICAL SCHEDULE	
1	Problems in consumer utility maximization
2	Estimation of income and substitution effects; Estimation of Consumer's surplus, equivalent variation and compensating variation
3	Estimation of demand models – Linear expenditure system
4	Estimation of demand models – Almost Ideal Demand System
5	Derivation and estimation of labour supply equations from household models
6	Solving problems in comparative static analysis of changes in demand for commodities due to changes in prices and income
7	Solving problems in price determination under perfect competition and monopoly
8	Solution concepts in game theory
9	Solving problems in oligopoly using Game theory models. Problem Solving in Monopolistic Competition
10	Market failure - Incomplete markets - Externality problem – Network externality. Public goods
11	Asymmetric information – Principal - Agent problem and Moral hazard - Transaction cost economics
12	General Equilibrium Theory - Conditions and Concepts, General equilibrium with Production and Consumption
13	Market equilibrium - Existence, Uniqueness, Stability of the market equilibrium. Walrasian general equilibrium mode
14	General competitive equilibrium - definitions, Fixed point theorem, existence, uniqueness and stability of general competitive equilibrium
15	Welfare Economics - Concepts, Problems, approaches and limitations of Welfare

	Economics
16	Applications of theory of welfare economics in structuring taxes, prices, investment, employment, international trade, and optimal pricing
17	**Final practical examination**
SUGGESTED READINGS	
1	Koutsoyiannis, A., 1973. "Modern Microeconomics, (London: The MacMillan Press Ltd.).
2	Chiang, Alpha C., 1981.Fundamental Methods of Mathematical Economics, New York: McGraw-Hill.
3	Henderson, J.M. and R.E. Quandt, 1958. Microeconomic Theory: A Mathematical Approach,
	New York: McGraw-Hill.
4	David .M.Kreps. 1990. *A Course in Microeconomic Theory.* Princeton Univ. Press.
5	Silberberg, E., and W.Suen, 2000.The Structure of Economics – A Mathematical Analysis, New York: McGraw-Hill Book Company.
6	Varian, Hal, R., 1992. Microeconomic Analysis, New York: W.W. Norton & Company.
7	Varian, Hal, R., 1999. Intermediate Microeconomics, New Delhi: Affiliated East-West Press.
8	Pindyck, Robert S. and Daniel L. Rubinfeld., 2017. Microeconomics, New Delhi: Pearson Publications.
SUGGESTED WEBSITES	
1	www.ocw.mit.edu
2	http://www.kevinhinde.com/
3	http://economicsonline.co.uk
4	http://economicsnetwork.ac.uk
5	http://www.econ.ucsb.edu/~tedb/eep/eep.html.
6	http://www2.econ.iastate.edu/classes/econ501/Hallam/
OUTCOME EXPECTED	
After successful completion of the Course, the students will be able to understand Producer's equilibrium under different market structures and the strategies to attain them. Further, the students will be able to know the consequences of market failure and how to internalize the Externalities. The course also throws light on different approaches and limitations of Welfare Economics.	

AEC 602*	ADVANCED MACRO - ECONOMIC ANALYSIS	2+0

WHY THIS COURSE?

A deeper understanding of the conceptual and structural framework is imperative to develop vision of a student about how the knowledge of various macroeconomic models is applied in real economy.

OBJECTIVE

To understand the functioning of national economy, its history and models. The policies governing the modern economic system and concerned institutions.

THEORY

UNIT I: Review of Macroeconomics concepts

Review of Macro Economics concepts - Comparative statics - Keynesian theory - Consumption Function and Theories of Consumption - Saving Function and Theories of Saving.

UNIT II: IS - LM Dynamics

Theories of Investment - Savings and Investment Equality - IS - LM Framework and its Extension - Demand for and Supply of Money-Monetary Policy in the static model – Inflation.

UNIT III: Open Macroeconomic Models

Stagflation and Supply side Economics - Theory of Unemployment - Phillips Curve controversy - Inflation, Productivity and distribution - Fiscal policy: Effectiveness and Problems.

UNIT IV: Dynamic Macroeconomic Models

Social Accounting Matrix Framework - General Equilibrium Analysis - Neo classical Macro Economics - Stochastic Macro Economics.

UNIT V: Macroeconomic Institutions and Policies

BOP & Adjustment Policies - Foreign Exchange Policy - Foreign sector : Capital and Current Account - Impact of WTO on Indian Economy - Impact of IMF & IBRD on Indian Economy - Reviewof Macro Economic Policies in India.

LECTURE SCHEDULE

1	Review of Macro Economics
2	Comparative statics and Keynesian theory
3	Consumption Function
4	Theories of Consumption

5	Saving Function
6	Theories of Savings
7	Theories of Investment
8	Savings and Investment Equality
9	IS – LM Framework
10	IS - LM Framework and its Extension
11	Demand for and Supply of Money
12	Monetary Policy in the static model
13	Inflation: Effects and control measures
14	Stagflation and Supply side Economics
15	Theory of Unemployment
16	Phillips Curve controversy – Inflation, Productivity and distribution
17	Fiscal policy: Effectiveness and Problems.
18	Effectiveness of Monetary Policy
19	Government's Budget Constraint and Fiscal Policy
20	Social Accounting Matrix Framework
21	SAM Extension
22	SAM and its Implications for Macro Economic Planning
23	General Equilibrium Analysis
24	Neo classical Macro Economics
25	Extension of Neo Classical Economics
26	Stochastic Macro Economics
27	Open Economy Macro Economics: Foreign Trade Multiplier
28	Balance of Payment
29	BOP Adjustment Policies
30	Foreign Exchange Rate
31	Foreign sector: Capital and Current Account
32	Review of Macro Policies in India -I
33	Review of Macro Economic Policies in India –II

SUGGESTED READINGS	
1	Macro Economics: Theory and Policy : Willam H. Branson (Londan : Harper & Row Publishers, 1977)
2	Macro Economics: Theory and Policy : Gardner Ackely (Londan : Collier Macmillion Publishers, 1987)
3	Macro Economics: Theory and Policies Sixth edition : Richard T. Frogen (New Jessey: Prentice Hall Sixth edition International Inc., 1999)
4	Macro Economic Analysis: Edward Shapiro (New Delhi : Galgotia Publications Private Limited, 1989)
5	Macroeconomics: Eugene A.Diulio (Schaums' Outlines, 4th Edition, 2006)
6	Stability with Growth: Macroeconomics, Liberalization and Development: Joseph Stigletz, Jose Antonio Oocampo, Shari Spiegel, Ricardo French-Davis and Deepak Nayyar (UN: ECLAC, 2006)
7	Economics: Paul. A. Samuelson and William D.Nordhaus (New Delhi: McGraw-Hill, 2004)
SUGGESTED WEBSITES	
1	http://ocw.mit.edu/courses/economics/14-02-principles -of -macroeconomics-fall-2009/
2	http://www.uh.edu/~bsorense/Macro_Lecture_Notes.pdf
3	http://www.econclassroom.com
4	http://wwwgetyourecon.com
5	http://www.cals.ncsu.edu/couse/are012/notes.html/

OUTCOME EXPECTED

After successful completion of this course the student will be able to-Figure out how policies are framed to safeguard the national economy. Understand the rationale behind the working of different economy.

AEC 603*	ADVANCED APPLIED ECONOMETRICS	2+1

WHY THIS COURSE?

The heart of any research is carrying out the model. The results obtained are crucial for the researchers. Thus this course acts as the centre point of building up analytical frame work of research. The students need to learn building up of models that will be used to test the hypothesis framed. Use different analysis depending upon the requirement and type of data.

OBJECTIVE

The course aims at providing quantitative econometric modeling skills and which the knowledge and command over analysis of data collected to get the desired result. Train the student in use of econometric models.

THEORY

UNIT I: Review

Review of classical regression model Probabilities, conditional probabilities and regression models – review of hypothesis testing – restrictions on parameters – single equation techniques.

UNIT II: Concept of Least Squares

Ordinary least squares specification, Assumption and estimation – weighted least squares-generalized least squares – instrumental variables method - maximum likelihood method - errors in variables, non-linearity and specification tests – non-spherical error terms. Violation of OLS assumptions causes, Nature, Consequences and Remedy.

UNIT III: Dummy Variable

Dummy variables - Qualitative and truncated dependent variables - limited dependent variables –LPM, probit and logit models, their multinomial extensions.

UNIT IV: Models and Their Extensions

Autoregressive distributed lag models – panel data fixed and random effects models and their extensions. Spatial econometrics, Structural Equation method, Sample Selection model.

UNIT V: Simultaneous Equation Models

Simultaneous equation methods –identification – estimation by indirect least squares - 2SLS, FIML, SURE, 3SLS.

PRACTICALS

Estimation of multiple regression model - GLS estimation methods - testing misspecification errors

– Testing and Managing multicollinearity, heteroscedasticity and autocorrelation - estimation of LPM, Logit and Probit models - comparing two regressions - Chow test - estimation of distributed lag models – panel data random and fixed effects models - Indirect least squares 2SLS, SURE, 3SLS, estimation of simultaneous equation models.

LECTURE SCHEDULE	
1	Nature and scope of econometric models, single and systems of equations
2	Probabilities, conditional probabilities and regression modeling
3	Approaches to statistical inference and hypothesis testing
4	Desirable properties of estimators- small and large sample properties
5	Classical regression model, specification, assumptions and estimation
6	Variants of OLS – weighted, restricted regression models – use of dummy variables
7	Maximum likelihood approach to the estimation of regression models
8	Properties of OLS and statistical inference
9	Violations of OLS assumptions and Consequences
10	Generalized Least Squares Method (GLS)
11	Feasible generalized least squares (FGLS) to accommodate non-spherical error terms
12	Multicollinearity - Causes, Nature, Consequences and Remedy
13	Heteroscedasticity - Causes, Nature, Consequences and Remedy
14	Autocorrelation- Causes, Nature, Consequences and Remedy
15	Errors in variables and their accommodation - Specification Bias and specification tests
16	Limited dependent variables-Qualitative and truncated dependent variables in regression models
17	Specification and estimation of LPM, probit, tobit and logit models
18	Multinomial extensions of limited dependent variable models
19	Autoregressive and distributed lag models
20	Nerlovian Supply Response Model
21	Adaptive expectations, Koyack Model
22	Spatial Econometric models
23	Structural Equation and sample selection models
24	Specification of panel data models
25	Fixed effects and Random Effect model specification and estimation
26	Extensions of panel data models
27	Specification of simultaneous equation regression models
28	Structural models and reduced form models
29	Identification of simultaneous equation models.

30	Approaches to estimation of simultaneous equation models. Single equation approaches - Indirect least squares,
31	2SLS, Instrumental variables estimation
32	System approaches - SURE
33	3SLS and Interpretation of simultaneous equation models
PRACTICAL SCHEDULE	
1	Estimation of multiple regression model and GLS estimation method
2	Testing for specification errors
3	Statistical inference with parameter restrictions
4	Estimation in the presence of multicollinearity
5	Estimation in the presence of heteroscedasticity through FGLS
6	Estimation in the presence of autocorrelation through FGLS
7	Estimation of LPM and Logit models
8	Estimation of Probit and Tobit models
9	Tests of structural change-Chow tests and tests of Causation (Granger's test)
10	Estimation of supply response and distributed lag models
11	Estimation of fixed effects panel data model
12	Estimation of random effects panel data model
13	Identification of simultaneous equation models (SEM)
14	Estimation SEM through single equation methods, indirect least squares and 2 SLS
15	Estimation of SURE model
16	Estimation of simultaneous equations by system method-3SLS
17	**Final practical examination**
SUGGESTED READINGS	
1	Greene, W.H. 2002. Econometric Analysis. Pearson Education Pvt Ltd, Delhi, 2002.
2	Johnston, J. and Dinardo, J. 2000. Econometric Methods. McGraw-Hill.
3	Koutseyianis, A. 1997. Theory of Econometrics. Barner & Noble.
4	Harry. H.Kelejan, and Walace E.Oates, Introduction to Econometrics - Principles and Applications" (NewYork: Harper and Row Pub.2001).
5	Maddala G.S., Econometrics (New York: McGraw Hill Book Co., 2002).
6	Maddala G.S. 1983. Limited Dependent and Qualitative Variables in Econometrics, Cambridge University Press.
7	Wooldridge, Jeffrey M. Econometric Analysis of Cross Section and Panel Data. MIT Press, 2001.
8	Gujarati, D., & Porter, D. (2008). Basic Econometrics. McGraw-Hill/Irwin.
9	Jeffrey M. Wooldridge, Introductory Econometrics, South-Western Publishing Co., 2000.
SUGGESTED WEBSITES	

1	http://www.oswego.edu/~kane/econometrics/stud_resources.htm
2	http://nickchk.com/econometrics.html
3	https://inomics.com/insight/top-youtube-channels-to-learn-econometrics-economics-

OUTCOME EXPECTED

After successful completion of the course, the student will be able to analyze the data collected for

testing the framed hypothesis. Get expertise in analytical framework.

AEC 604*	ADVANCED PRODUCTION ECONOMICS	2+1

WHY THIS COURSE?

There is requirement of getting acquainted with decision making process in case of factors and products. The researcher needs to understand about working on production process and workout suitable suggestions to improve it.

OBJECTIVE

The course curriculum is designed to expose the scholars to advanced models in agricultural production decisions. To expose the scholars to advanced production economics principles and their applications; and to train the research scholars in advanced production economics tools for decision making and policy analysis. The course would also cover the analysis of production functions, its interpretation, decision making with multiple input use, factor sharing and decision making under risk and uncertainty.

THEORY

UNIT I: Production Process

Agricultural Production process – Relationship between farm planning and production Economics

- Scope of agricultural production and planning-methods/procedures in agro-economic research and planning.

UNIT II: Production Functions and Characteristics

Production functions, components, assumptions, properties and their economic interpretation - Concepts of homogeneity, homotheticity, APP, MPP, elasticities of substitution and their economic relevance – Production relations – optimality – Commonly used functional forms nature, properties, limitations, estimation and interpretation linear, Spillman - Cobb Douglas, quadratic, multiplicative (power) functional forms - Translog, and transcendental functional forms - CES, production functional forms. Conceptual and empirical issues in specification, estimation and application of production functions- Analytical approaches to economic optimum - Economic optimum– determination of economic optimum with constant and varying input and output prices -

Economic optimum with production function analysis - input use behaviour.

UNIT III : Decision Making in Production

Decision making with multiple inputs and outputs – MRT and product relationship-cost of production and adjustment in output prices - Single input and multiple product decisions - Multi input, and multiproduct production decisions - Decision making with no risk - Cost of wrong decisions - Cost curves – Principles and importance of duality theory - Comparison of production, cost, and profit functions - Principles and derivation of demand and supply functions.

UNIT IV: Technology, Efficiency and Risk Management

Technology, input use and factor shares - Effect of technology on input use decomposition analysis- Factor shares-estimation methods- Economic efficiency in agricultural production – technical, allocative and economic efficiency – measurement Yield gaps analysis – concepts and measurement - Risk and uncertainty in agriculture –incorporation of risk and uncertainty in decision making – risk and uncertainty and input use level-risk programming.

UNIT V: Optimization through Programming

Programming techniques in agricultural production-Multiple Objective Programming (MOP) –

Goal programming, Weighted sum and Compromise Programming – applications.

PRACTICALS

Estimation of different forms of production functions- Optimal input and product choice from estimated functions-Derivation of demand and supply functions and estimation. Estimation of cost function and interpretations-Optimal product and input choice under multi input and output system-Estimation of factor shares from empirical functions estimated-Estimating production functions incorporating technology changes: Decomposition analysis and incorporation of technology-Estimation of efficiency measures – Stochastic, probabilistic and deterministic frontier production functions-Risk programming – MOTAD-Quadratic programming-Simulation models for agricultural production decisions-Goal programming – Weighted, lexicographic and fuzzy goal Programming - Compromise programming.

LECTURE SCHEDULE

1	Agricultural Production Process – Production functions, components, assumptions, properties and their economic interpretation.
2	Concepts of homogeneity, homotheticity in production function. APP, MPP Elasticities of substitution and their economic relevance.
3	Mathematical analysis of input-output, input-input and product-product relationships
4	Optimality of production process - LDR
5	Commonly used functional forms, nature, properties, limitations, estimation and interpretation
6	Linear, Spillman and Cobb Douglas functional forms
7	Quadratic and Multiplicative (power) functional forms.
8	Translog, and transcendental functional forms

9	CES production function - form, properties and applications
10	Conceptual and empirical issues in specification, estimation and application of production functions
11	Economic optimum – determination of economic optimum with constant and varying input and output prices
12	Economic optimum with production function analysis - input use behaviour
13	Decision making with single input and multiple product decisions
14	Decision making with Multi input and multi production decisions
15	Decision making with no risk -Cost of wrong decisions – decision making with varying input supply and input use behaviour
16	Cost curves and cost functions– cost and production relationships
17	Principles and importance of duality theory
18	Comparison of production, cost, and profit functions
19	Principles and derivation of input demand and output supply functions
20	Technology, and input use -effect of technology on input use-decomposition analysis
21	Factor shares -estimation – accounting method – production function method
22	Concepts and measurement of efficiency in agricultural production – technical, allocative and economic efficiency
23	Measurement of technical efficiency – Stochastic frontier production function analysis
24	Measurement of technical efficiency - Data Envelopment Analysis (DEA) with bootstrapping
25	Yield gaps analysis – concepts and measurement
26	Risk and uncertainty in agriculture – incorporation of risk and uncertainty in decision making- Input use decisions under risk and uncertainty
27	Risk programming – MOTAD and Quadratic programming
28	Simulation techniques – importance in agricultural production decisions – types of simulations and applications
29	Multiple Objective Programming (MOP) – importance and applications in agricultural production
30	Multiple Objective Programming (MOP) – Estimation and interpretation of MOP
31	Goal programming – Weighted goal programming,
32	Lexicographic Goal programming and its applications
33	Compromise programming – importance and applications
PRACTICAL SCHEDULE	
1	Preparation of field data for empirical estimation of functional forms
2	Estimation of linear, quadratic, power, Spillman functions
3	Estimation of Translog and transcendental functions

4	Estimation of CES and VES production functions and interpretations
5	Optimal input and product choice from estimated functions
6	Derivation of input demand and output supply functions
7	Estimation of cost function and interpretations
8	Optimal product and input choice under multi input and output system
9	Estimation of factor shares from empirical functions estimated
10	Estimating production functions incorporating technology changes: Decomposition analysis and incorporation of technology
11	Estimation of efficiency measures – Stochastic, probabilistic and deterministic frontier production functions
12	Risk programming – MOTAD model
13	Risk programming – Quadratic programming
14	Simulation models for agricultural production decisions
15	Goal programming – Weighted, lexicographic and fuzzy goal programming
16	Compromise programming
17	**Final practical examination**
SUGGESTED READINGS	
1	Palanisami, K. P. Paramasivam and C. R. Ranganathan. Agricultural Production Economics: Analytical Methods and Applications, (New Delhi: Associated Publishing Co.,), 2002.
2	David L. Debertin , Agricultural Production Economics, (New Jersey: Macmillan Publishing Company, second edition), 2012.
3	Heady E.O. Economics of Agricultural Production and resources use. Practice Hall of India.
4	Heady E.O. & Dillon, J L. 1961. Agricultural Production functions. Kalyani Publishers, Ludhiana, India. 667 p.
5	Baumol, W.G. 1973. Economic theory and operations analysis. Practice Hall of India Private Limited, New Dehli.626 p.
6	Gardner BL & Rausser GC. 2001. Handbook of Agricultural Economics Vol. I Agricultural Production. Elsevier.
7	Heady, Earl O., and John L.Dillon, Agricultural Production Functions" (Ames: Iowa State University Press), 2012.
SUGGESTED WEBSITES	
1	http://ocw.mit.edu/courses/economics
2	https://www.msu.edu/course/ECO/855
3	http://www.uky.edu/~deberti/prod/agprod5.pdf

4	http://www.csuchico.edi/ag/assets/documents/syllabi/ABUS/ABUS%20301%20AG%20production%20Econ%20Analysis.pdf

OUTCOME EXPECTED

After successful completion of the course, the student will be able to get familiar with different production functions and use them in practice and come out with useful decision. Workout the efficiency of the production process and use models for finding the optimum solution.

RPE 601*	RESEARCH AND PUBLICATION ETHICS	2+0

OVERVIEW

This course has total of 6 units focusing on basics of philosophy of science and ethics, research integrity, publication ethics. Hands-on-sessions are designed to identify research misconduct and predatory publications. Indexing and citation databases, open access publications, research metrics (citations, h-index, Impact Factor, etc) and plagiarism tools will be introduced in this course.

OBJECTIVE

The course is for awareness about the publication ethics and publication misconducts.

PEDAGOGY

Class room teaching, guest lectures, group discussions and practical sessions.

EVALUATION

Continuous assessments will be done through tutorials, assignments, quizzes and group discussions. Weightage will be given for active participation. Final written examination will be conducted at the end of the course.

THEORY

Unit I: Philosophy and Ethics – Scientific Conduct

Introduction to philosophy: definition, nature and scope, concept, branches.

Ethics: definition, moral philosophy, nature of moral judgements and reactions.

Ethics with respect to science and research.

Intellectual honesty and research integrity.

Scientific misconducts: Falsification, Fabrication and Plagiarism (FFP).

Redundant publications: duplicate and overlapping publications, salami slicing.

Selective reporting and misrepresentation of data.

Unit II: Publication Ethics

Publication Ethics: definition, introduction and importance.

Best practices / standards setting initiatives and guidelines: COPE, WAME, etc.

Conflicts of interest.

Publication misconduct: definition, concept, problems that lead to unethical behavior and vice-versa, types.

Violation of publication ethics, authorship and contributorship.

Identification of publication misconduct, complaints and appeals.

Predatory publishers and journals.

Unit III: Open access publishing

Open access publications and initiatives.

SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies.

Software tool to identify predatory publications developed by SPPU.

Journal finder / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

Unit IV: Publication misconduct

A. Group discussions

Subject specific ethical issues, FFP, authorship

Conflicts of interest.

Complaints and appeals: examples and fraud from India and abroad

B. Software tools

Use of plagiarism software like Turnitin, Urkund and other open source software tools.

Unit V: Databases and Research Metrics

A. Databases

Indexing databases.

Citation databases: Web of Science, Scopus, etc

B. Research Metrics

Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score.

Metrics: h-index, g index, i10 index, altmetrics.

References:

Bird, A. (2006).Philosophy of Science, Routledge.

MacIntyre, Alasdair (1967) A Short History of Ethics. London.

P.Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN: 978-9387480865.

National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). On Being a Scientist: A Guide to Responsible Conduct in Research: Third edition, National Academies Press.

Resnik, D.B. (2011). What is ethics in research & why is it important. National Institute of Environmental Health Sciences, 1-10. Retrieved from https://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfm

Beall, J. (2012). Predatory publishers are corrupting open access. Nature, 489(7415), 179. https://doi.org/10.1038/489179a Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance (2019), ISBN: 978-81-939482-1-7. http://www.insaindia.res.in/pdf/Ethics_Book.pdf

AEC 605	ADVANCED AGRICULTURAL MARKETING AND PRICE ANALYSIS	1+1

WHY THIS COURSE?

The aim of production process is to sell the produce in the market and generate income. Markets serve as platform where this exchange takes place. Agriculture markets are different from other markets due to the nature of the commodity. Thus, it is important to develop a strong foundation of agricultural marketing, its components and issues. The student needs to know about the multi-pronged ways of marketing the produce, agencies involved. In this modern era, it is important to

understand how technology is transforming this sector.

OBJECTIVE

The main objective of this course is to critically analyze the important marketing concepts,

models, properties of agricultural commodity prices and forecasting, data collection and analysis using computer software in order to make policy decisions in the field of agricultural marketing.

THEORY

Unit I: Agricultural Marketing Institutions

Importance of market analysis in the agricultural system - Role of various formal institutions in agricultural marketing – objectives and functions – measuring their efficiency – public-private-partnership – institutional arrangements. Successful case studies.

Unit II: Market Analysis

Multi market estimation – Supply response models – Market integration and price transmission – Supply / Value chain analysis.

Unit III: Introduction to Forecasting

Forecasting - Lag operators and difference equations – Stationary and stochastic processes – Unit roots and cointegration – Conditional heteroscedasticity - Price volatility estimation – ARCH models – GARCH models – Forecast evaluation.

Unit IV: Methods of Forecasting

Methods of forecasting – ARMA – ARIMA – SARINA (Simulation and Prediction with Seasonal ARIMA models) – ARFIMA (Auto Regressive Fractional Integrated Moving Average Model).

Unit V: Application of Modern Techniques

Application of remote sensing data – big data analysis – Application of Artificial Intelligence tools – deep learning – Price forecasting - Price indices – construction and application.

PRACTICALS

Estimation of demand / Supply forecasting – Supply chain / Value chain analysis for different

commodities – Commodity models – Multi market estimation – Time series analysis – Market integration studies – Price discovery – Price volatility estimation – Commodity price forecasting.	
LECTURE SCHEDULE	
1	Various formal institutions in agricultural marketing – Objectives and functions – Measuring their efficiency
2	Multi market estimation – Fundamentals, Construction and Application
3	Multi-market model – IFPRI.
4	Supply response models – Theoretical frame work and building
5	Market integration – Unit roots and co integration – VECM approach
6	Price transmission – Fundamentals and Theoretical frame
7	Supply / value chain analysis for different commodities
8	Lag operators and difference equations – Construction and Application
9	Stationary and stochastic processes – Unit roots – Unit root test - Application
10	Cointegration – VECM approach
11	Price volatility estimation – ARCH and GARCH models – Theoretical frame work and building
12	Forecast evaluation
13	Methods of forecasting – Naïve models – MA, AR, ARMA – ARIMA (Box-Jenkins approach)
14	Application of remote sensing data- big data analysis
15	Application of Artificial Intelligence tools – deep learning – price forecasting
16	Price indices – Theoretical frame work – Construction and Application
PRACTICAL SCHEDULE	
1	Estimation of demand elasticity and demand forecasting
2	Estimation of supply elasticity and supply forecasting
3	Market Equilibrium Analysis
4	Supply chain / value chain analysis different agricultural commodities, milk and poultry products
5	Chain Analysis - quantitative estimation of supply chain efficiency
6	Commodity models – Fundamentals, Construction, Estimation and Application
7	Multi market estimation - Fundamentals, Construction and Application
8	Time series analysis – Decomposition of time series data (daily, weekly, monthly and quarterly data)
9	Market integration – Simple correlation and Ravallion model analysis and interpretation
10	Market integration –. Granger Causality, Unit roots, ADF test, VECM estimation
11	Price discovery price volatility – ARCH models – GARCH models -other hybrid models Estimation
12	Forecasting – Naïve models – Single and Double Exponential Smoothing estimation
13	Price forecasting using– MA, AR, ARMA, ARIMA and Box-Jenkins estimation

14	Commodity price forecasting using software's - charts
15	Application of Difference equations in Agricultural Commodity model estimation
16	Application of remote sensing data in agricultural Marketing (current crop condition estimates) – **Guest Lecture**
17	**Final practical examination**

SUGGESTED READINGS	
1	Timmer, C.P. 1986. Getting Prices Right. Ithaca, N.Y.: Cornell University Press
2	Hallam, D. 1990. Econometric Modeling of Agricultural Commodity Markets. New York: Routledge
3	Goodwin, J.W. 1994. Agricultural Price Analysis and Forecasting. New York: Wiley
4	Martimort, D. ed. 1996. Agricultural Markets: Mechanisms, Failures, and Regulations. New York : Elsevier
5	Ferris, J.N. 1998. Agricultural Prices and Commodity Market Analysis. New York: McGraw-Hill
6	Schrimper, R.A. 2001. Economics of Agricultural Markets. London: Pearson
7	Tomek, W.G., and K.L. Robinson. 2003. Agricultural Product Prices. 4th ed. lthaca, N.Y.: Cornell University Press
8	Nilabja Ghosh (2013) India's Agricultural Marketing-Market Reforms and Emergence of New Channels. Springer New Delhi- for new institutional arrangements in agricultural marketing, channel efficiency, PPP initiatives and case studies

SUGGESTED WEBSITES	
1	http://courses.cals.uidaho.edu/aers/agecon289/Index.htm
2	http://www.uky.edu/Classes/AEC/305- 001/classppts/01.pdf
3	http://www.youtube.com/watch?v=1vixHc37DII
4	http://www.stanford.edu/group/FRI/indonesia/.../chapt4.fm.
5	html http://www.Franciscovergara.Com/Pricecontrols.doc
6	http://www.docstoc.com
7	http://en.wikipedia.org/wiki/Market_structure
8	http://pdf.usaid.gov/pdf_docs/PNADL965.pdf
9	http://ageconsearch.umn.edu/handle/47883
10	http://faculty.quinnipiac.edu/charm/CHARM%20proceedings/.../160%20faria.pdf

OUTCOME EXPECTED

After the completion of this course the student will be able to-

- Understand the whereabouts of agricultural marketing.
- Acquisition analytical skills in addressing the issues of agricultural marketing
- Be familiar with the different forms of marketing in this sector.
- Reap expertise in improving the performance of the marketing institutions
- Gain expertise in market intelligence and price forecasting.

AEC 607	QUANTITATIVE DEVELOPMENT POLICY ANALYSIS	1+1

WHY THIS COURSE?

Policy reforms are inevitable. They are continuously required to deal with the loop holes of previous policy and control the present situation in a better manner. Reforms take place in both microeconomic and macroeconomic policies. The analysis of these policies help us to develop a framework for designing and implementing the policies.

OBJECTIVE

To develop expertise in understanding the rationale behind development of policies. Conceptualization of equilibrium and working out the economic implications of development policy.

THEORY

Unit I: Overview of QDP

Policy framework – goals, value, beliefs and welfare maximization. Market – Policy and State – State vs Market – Failure of Policy – Failure of Markets - Rationale for Government Intervention. Role of Quantitative Policy Analysis.

Unit II: Demand and Supply Analysis

Demand analysis for policymaking – Alternative approaches to demand analysis – Policy implications. Supply response – Alternative approaches to measurement of supply response – Nerlovian models of supply response – Policy implications.

Unit III: Household Models

Household behaviour and policy analysis – Household models**.**

Unit IV: Partial Equilibrium Analysis

Partial equilibrium analysis – Concept of reference prices – Price distortions – indicators and impact. Transaction costs – Implications for efficiency and productivity – Institutional solutions - Multi market approach to policy analysis.

Unit V: General Equilibrium Analysis

Social Accounting Matrices and multipliers -– Computable General Equilibrium models to assess economy wide impact of policy changes.

PRACTICALS

Review of criteria for policy evaluation – Estimation of price elasticities – Review of estimation of complete demand systems – Estimation of Nerlovian supply Response model – Review of Household models – Specification and estimation of household models – Partial equilibrium analysis – Input–output table – Social Accounting Matrix – Construction of a SAM – computation of Multipliers – Multi Market Analysis – Review of Computable General Equilibrium Models.

LECTURE SCHEDULE	
1	Policy framework – goals, value, beliefs and welfare maximization
2	Approaches to Development theory: Market, Policy and State
3	Rationale for Government Intervention
4	Role of Quantitative Policy Analysis
5	Demand analysis for policymaking
6	Alternative approaches to demand analysis – Policy implications.
7	Supply response- Alternative approaches to measurement of supply response
8	Nerlovian models of supply response – Policy implications
9	Household behavior and policy analysis – Household models
10	Partial equilibrium analysis
11	Concept of reference prices – Price distortions – indicators and impact
12	Transaction costs – Implications for efficiency and productivity
13	Institutional solutions
14	Multi market approach to policy analysis
15	Social Accounting Matrices and multipliers
16	Computable General Equilibrium models to assess economy wide impact of policy changes
PRACTICAL SCHEDULE	
1	Review of criteria for policy evaluation
2	Technological change and factor substitutability
3	Estimation of price elasticities for policy analysis-I
4	Estimation of price elasticities for policy analysis-II
5	Review of estimation of complete demand systems
6	Estimation of Nerlovian supply Response model
7	Review of Household models
8	Specification and estimation of household models
9	Estimation of household response to price incentives
10	Partial equilibrium analysis – Input–output table
11	Social Accounting Matrix – Construction of a SAM
12	Computation of Multipliers
13	Multi Market Analysis
14	Policy analysis with multi market analysis
15	Review of Computable General Equilibrium Models
16	Policy analysis through CGE models
17	**Final practical examination**

SUGGESTED READINGS	
1	Kindleberger, P. Charles, "Economic Development" (London :(Mcgrew Hill International Book Company), 1977.
2	Ghatak Subrata and Ken Ingersent, "Agriculture and Economic Development" (New Delhi: Select Book Service Syndicate), 1984.
3	Chenery. H and T.N. Srinivasan eds., (1988), Hand book of Development Economics, (Amsterdam: North-Holland).
4	Ellis Frank, "Agricultural Polices in Developing Countries" (New York : Cambridge University Press), 1992.
5	John, and J. Walley (1992), Applied General Equilibrium (New York: Cambridge University Press).
6	Sadoulet Elizabeth and Alain de Janvry (1995), Quantitative Development Policy Analysis, (London: The John Hopkins University Press).
7	Eicher, K.C., and John M. Staatz, "International Agricultural Development". (Baltimore: The Johns Hopkins University Press), 1998.
8	Meier, M. Gerald and Stigilitz J.E. (2001), Frontiers of Development Economics- the future perspective, (New York: Oxford University Press).
9	Fischer Gerald, J. Miller and Mara S. Sidney, eds, Handbook of Public Policy Analysis: Theory, Politics and Methods (Boca Raton, Fla.: CRC Press, 2007).
10	Shoven Neck, Reinhard; Christian Richter and Peter Mooslechner, "Quantitative Economic Policy", Essays in Honour of Andrew Hughes Hallett (Eds), 2008.
SUGGESTED WEBSITES	
1	http://www.lib.cam.ac.uk/
2	http://www.grlc.vic.gov.au/content/collection-development-policy
3	http://library2.jfku.edu/about/cd_policy.html
4	http://www.mga.edu/library/policies.aspx
5	http://www.libs.uga.edu/colldev/cdpolicy.html

OUTCOME EXPECTED

After the completion of the course, the student will be able to conceptualize policy framework.

Get acquainted with analyzing the policy and work out corrective solutions.

AEC 607	ADVANCED NATURAL RESOURCE ECONOMICS	1+1

WHY THIS COURSE?

Agriculture is concerned with human interaction with natural resources for producing and consuming basic human necessities. In the course of these activities humans exploit various natural resources often in ways that are not sustainable in the long run. In this context, the students of agricultural economics need a systematic understanding of problems facing natural resource exploitation and its relationship with the economy and society. Hence this course is designed to provide a systematic understanding of the resource dynamics, depletion and methods for optimal intertemporal allocation of scarce natural resources.

OBJECTIVE

This course explores how to apply principles of economics to identify the causes, consequences, and ways of dealing with natural resource problems. The primary objective is to develop students' skills in using economic concepts to analyze contemporary issues associated natural resource uses and policies. The major topics covered in this course include:

- Defining inter temporal (dynamic) economic efficiency and other criteria for evaluating natural resource use and policy.
- Application of optimal control / dynamic programming methods to design optimal resource extraction policies over time. The resources covered include exhaustible mineral resources, renewable resources such as fisheries, forests, and water resources.
- Examining sources of inefficiency in the exploration of natural resources.
- Property rights issues in natural resource management and
- Issues concerning the nexus between economic development, poverty and natural resource degradation.

THEORY

Unit I: Dynamics of Natural Resources

Natural resources - Definition - characteristics and classification. Stock dynamics of renewable and non-renewable resources. Equation of motion for renewable and non- renewable resources.

Fundamental equation of renewable resources.

Unit II: Efficiency in Natural Resource Use

Growth curves of fishery and forest resources. The role of time preference in natural resource use. Simple two-period model of optimal use of renewable and non-renewable resources. Advanced models of optimal resource use – Static Vs. dynamic efficiency in natural resource use Applications of dynamic programming and optimal control.

Unit III: Natural Resource use in Agriculture

Economics of groundwater use - optimal extraction of groundwater. Analytical and numerical solutions for optimal inter-temporal allocation of natural resources. Optimal harvesting of single

rotation and multiple rotation forests. Optimal management of fishery.

Unit IV: Open Access and Common Property Resource Management

Property rights in natural resources and their implication for conservation and management of natural resources. Management of common property natural resources – Institutional arrangements for conservation and management of common pool fishery, groundwater and forestry resource. Local and global commons.

Unit V: Natural Resource Scarcity, Resource Degradation, Resource Pricing and Valuation

Resource scarcity – Resource curse hypothesis - Natural resource degradation – Poverty and

resource degradation – Natural resource accounting - Pricing and valuation of natural resources – Natural resources policy. Forestry policies – Irrigation water management policies.

PRACTICALS

Derivation of the fundamental equation of renewable resources-Estimation of growth curves and stock dynamics for fishery and forestry resources. Simple two period problem of optimal resource use – Numerical solution for simple two-period model of dynamic efficiency in natural resource extraction. Multi-period dynamic efficiency –Solving dynamic natural resource harvesting problems. Using analytical solution procedures for solving natural resource management

problems – Optimal control.

LECTURE SCHEDULE

1	Natural resources - definition - characteristics and classification
2	Stock dynamics of non-renewable resources - Equation of motion for renewable - Hotelling's Rule – Derivation and interpretation
3	Analysis of the impact of changes in interest rate, stock quantity, demand, and prices on extraction pattern of non-renewable resources
4	Stock dynamics of renewable -Equation of motion for renewable resources
5	Static Vs. dynamic efficiency in natural resource use – Steady state equilibrium
6	Derivation of Fundamental equation of renewable resources
7	Growth curves of fishery resources
8	Open access vs. private property equilibrium
9	Simple two-period model of optimal use of non-renewable resources

10	Simple two-period model of optimal use of renewable resources
11	Optimal inter temporal allocation of natural resources – Non-renewable resources.
12	Optimal harvesting of single rotation and multiple rotation forests and old-growth forests
13	Optimal management of fishery
14	Optimal extraction of groundwater
15	Economics of biodiversity
16	Role of property rights in natural resources and their implication for conservation and management of natural resources and management of common property resources
PRACTICAL SCHEDULE	
1	Mathematical modeling of natural resource problems
2	Estimation of growth curves and stock dynamics for fishery and forestry resources. Simple two period problem of optimal resource use
3	Numerical solution for simple two-period model of dynamic efficiency in natural resource extraction
4	Multi-period dynamic efficiency-Problem solving
5	Solving dynamic natural resource harvesting problems – Fisheries problem
6	Solving dynamic natural resource harvesting problems – Timber harvesting problem
7	Solving dynamic natural resource harvesting problems – groundwater extraction problem.
8	Solving dynamic natural resource harvesting problems – Mineral harvesting problem.
9	Using analytical solution procedures for solving natural resource management problems – Water allocation problem
10	Natural resource accounting – Problem solving
11	Analysis of water conservation and water allocation problems
12	Cooperative game theory problems in common pool natural resource management
13	Non-cooperative game theory problems in common pool natural resource management
14	Impact of wealth inequality on common pool natural resource management – Problems
15	Comparative analysis of open access, common property and private property equilibrium in natural resource exploitation
16	Natural resource valuation – Valuation techniques
17	**Final practical examination**
SUGGESTED READINGS	
1	Clark, C.W., Mathematical Bioeconomics: The Optimal Management of Renewable Resources" (New York: John wiley and Sons), 1976.
2	Fisher, A.C., Resource and Environmental Economics, (Cambridge: Cambridge University Press), 1981.
3	Chiang, Alpha C., Elements of Dynamic Optimization, (Illinois: Waveland Press), 1992.

4	Baland, J-M. andJ.P.Platteau, Halting Degradation of Natural Resources: Is There a Role for Rural Communities? Oxford: Clarendon Press and FAO, 1996.
5	Carlson, G.A., J. Miranowski and D.Zilberman, Agricultural and Environmental Resource Economics, Oxford: Oxford University Press, 1998.
6	Conrad, J.M. and Clark, C.W. Natural Resource Economics: Notes and Problems (Cambridge: Cambridge University Press).
7	Prato, T. Natural Resource and Environmental Economics, Ames: Iowa State University Press, 1998.
8	Conrad, J.M., Resource Economics, Cambridge: Cambridge University Press, 1999.
9	Sterner, T. Policy Instruments for Environmental and Natural Resource Management, (Washington, D.C.: Resources for the Future), 2003.
SUGGESTED WEBSITES	
1	www.rff.org
2	http://spot.colorado.edu/~kaplan/econ3535/econ3535.html, from where link can be established for eText at : chrome://epubreader/content/reader.xul?id=1
3	http://www.pearsonhighered.com/tietenberg/
4	www.env-econ.net/
5	http://personal.strath.ac.uk/r.perman/enviro7.htm
6	http://personal.strath.ac.uk/r.perman/EERclassnotes.htm
OUTCOME EXPECTED	
The students will get a thorough and comprehensive exposure to natural resource problems, the issues confronting optimal management, resource scarcity and overexploitation problems. They will also be conversant with the optimal management of natural resources using optimal control models. The students will become capable of using EXCEL Solver for solving optimal control problems.	

AEC 608	ENVIRONMENTAL ECONOMICS	1+1

WHY THIS COURSE?

Economics not only deals with transaction taking place between human beings within and across national boundaries. Each economic activity has a price to pay to the environment. The activity causes loss to the environment in various ways. Thus, as a student of economics it is necessary to work out the costs and returns in terms of losses to environment while carrying out these development/production activities.

OBJECTIVE

To understand the economic outcomes of environmental degradation. Make students proficient in decision making regarding environment protection, resource use, and conservation policy.

THEORY

UNIT I : Overview of Environmental Economics

Environmental pollution as a consequence of market failure - Causes and consequences of market failure - Externalities - Public goods and externalities - Economics of pollution – Private vs. Social cost of environmental pollution – Property rights, environment and development – Theory of environmental policy.

UNIT II: Economic Assessment

Environmental cost benefit analysis - Non-market valuation of environmental resources (WTP / WTA) - Environment, market and social welfare.

UNIT III : Developmental Aspects

Economic growth and environmental cost - Growth oriented economic policies and their environmental impacts - Population and environmental quality - poverty and environmental degradation.

UNIT IV: Accounting, Policies and Regulation Environment

Ecology and environmental accounting - Environmental pollution with respect to water and air - Land and forest resources related environmental pollution - Coastal externalities - Urbanization and environment - Basic approaches to environmental policy (Tax, subsidy, pollution permits etc.) Green taxes.

UNIT V: Environmental Issues

Economics of global warming, climate change and emission trading - Environment, international trade and development.

PRACTICALS
Contemporary global environmental global environmental issues, movement, policies, programmes, laws and other regulatory mechanisms - Criteria for evaluating the environment related projects and review of Environmental Impact Assessment (EIA) techniques – Recreation demand models of environmental valuation - Contingent valuation techniques - Environmental Resource Accounting Techniques - Discussion on the techniques dealing with air pollution and review of case studies on air pollution and its impacts - forest environment and wild life conservation - Green GDP and Green house insurance - Practical considerations and comparisonof instruments of environmental policy - Non-point source pollution control methodologies - Environment in macroeconomic modeling - Meta-analysis, economic valuation and environmental economics - Multi-criteria methods for quantitative, qualitative and fuzzy evaluation problems related to environment - Input output analysis, technology and the environment - Computable general equilibrium models for environmental economics and policy analysis

LECTURE SCHEDULE	
1	Environmental pollution as a consequence of market failure
2	Causes and consequences of market failure- Property rights, CPR and open access resources
3	Externalities – Private good, Public goods, club goods and externalities
4	Economics of Environmental goods - Private vs. Social Benefits and Private vs. Social Costs
5	Environment and development - Theory of environmental policy- Coase Theorem and Environmental Kuznets Curve.
6	Environmental cost benefit analysis
7	Total Economic Valuation of Environmental goods
8	Revealed Preference methods and Stated Preference methods
9	Environment, market and social welfare
10	Link between Population, Poverty and environmental quality
11	Environmental pollution with respect to Land and Water
12	Coastal externalities - Urbanization and environment
13	Polluter Pay Principle-Pigouvian taxes, Green taxes, Tradable Pollution Permits
14	Economics of Climate Change
15	History of Climate Agreements and Climate Funding
16	Carbon Trading

PRACTICAL SCHEDULE	
1	Contemporary global environmental issues, movement, policies, programmes, laws and other regulatory mechanisms
2	Criteria for evaluating the environment related projects and review of Environmental Impact Assessment (EIA) techniques

3	Contingent valuation techniques –WTP &WTA
4	Recreation demand models of environmental valuation
5	Review of case studies dealing with hedonic models
6	Environmental Resource Accounting Techniques
7	Case studies on Tradable pollution permits and carbon trading
8	Visit to problem sites to quantify the economic, environmental and ecological consequences of water pollution
9	Discussion on the techniques dealing with air pollution and review of case studies on air pollution and its impacts
10	Green GDP measurement
11	Practical considerations and comparison of instruments of environmental policy
12	Non-point source pollution control methodologies
13	Environment in macroeconomic modeling
14	Meta-analysis, economic valuation and environmental economics
15	Climate change impact assessment models
16	Case studies on carbon, water footprints estimation
17	**Final practical examination**
SUGGESTED READINGS	
1	Hackett SC. 2001. Environmental and Natural Resource Economics: Theory, Policy and the Sustainable Society. M.E. Sharpe, Armonk, NY.
2	Hartwick JM &Olewiler ND. 1998. The Economics of Natural Resource Use. 2 nd Ed Addison-Wesley Educational Publ.
3	Kerr JM, Marothia DK, Katar Singh, Ramasamy C & Bentley WR. 1997. Natural Resource Economics: Theory and Applications in India. Oxford & IBH.
4	Pearce DW & Turner K. 1990. Economics of Natural Resources and the Environment. John Hopkins Univ. Press.
5	Prato T. 1998. Natural Resource and Environmental Economics. Iowa State Univ. Press. Sengupta R. 2000. Ecology and Economy, an Indian Perspective. Oxford Univ. Press.
6	Tietenberg T. 2003. Environment and Natural Resource Economics. 6th Ed. Addison Wesley.
7	Bromley, W. Daniel, "The Hand Book of Environmental Economics" (Madison: Black Well Publications), 2005.
8	Nick Hanley, Jason F. Shogran and Ben White, "Environmental Economics in Theory and Practice", (Delhi : Mc Millan, India),2e. 2009.
9	Timothy C. Haab and Kenneth E. Mc Connell, "Valuing Environmental and Natural Resources – The econometrics of Non market valuation" (Edward Elgar Publishing Limited, UK), 2003.
10	Dixon, John A., Louise Fallon Scura, Richard A Carpenter and Paul B. Sherman, "Economic Analysis of Environmental Impacts of development projects" (London : Earth scan Publications Ltd.), 2013

11	Kenry turner, David prance, Ian Batsman and Johns Hopkins "Environmental Economics: An Elementary Introduction" 2013
12	The Economics of the Environment and Natural Resources Author(s):R. Quentin Grafton, Wiktor Adamowicz, Diane Dupont, Harry Nelson, Robert J. Hill, Steven Renzetti
SUGGESTED WEBSITES	
1	https://www.env-econ.net/recommended_reading/
2	https://onlinelibrary.wiley.com/doi/book/10.1002/9780470755464
3	https://www.worldscientific.com/doi/suppl/10.1142/6980/suppl_file/6980_chap01.pdf
4	https://www.worldscientific.com/doi/suppl/10.1142/6980/suppl_file/6980_chap02.pdf
5	https://www.worldscientific.com/doi/suppl/10.1142/6980/suppl_file/6980_chap08.pdf
OUTCOME EXPECTED	
After the successful completion of the course, the student will be able to understand the concept of pollution and externalities caused by economic activity. Work out the economics of productions activities in terms of losses to environment. Learn about accounting of environmental costs and other issues related.	

AEC 609	INTERNATIONAL TRADE THEORIES AND POLICY APPLICATIONS	1+1

WHY THIS COURSE?

In the modern world, there is trade across national boundaries and one economy has effect on the other. Getting familiar with the trade theories and its policy applications would result in better understanding of the national economy and its influence upon the world trade.

OBJECTIVE

The goal is to provide the students with background experience and tools for future analysis in international economic problems and trade policies.

THEORY

Unit I: International Trade Theories - An Introduction

Why do Nations Trade: Classical Theory - Ricardian Model of Trade - Factor Price Equalization Theorem - Stolper – Samuelson Theorem - The Rybczynski Theorem - The Heckscher Ohlin Theorem – New Trade Theory (NTT) – Contributions by Paul Krugman.

Unit II: Trade Equilibrium

Walras's Law and Trade Equilibrium - Factor Price and Factor Proportions of the Firm in Open Economy – Scitovsky's Social Indifference Curves – Factor Mobility – Equilibrium under NTT.

Unit III : Barriers to Trade

Trade Indifference Curves - Economics of Scale, Imperfect Competition and Trade- International Trade in the presence of product differentiation- Theory of Protection: Tariffs and Other Barriers to Trade – Arguments for Protection – Regional Blocks – FTA/ RTA.

Unit IV: Trade Dynamics

Sources of Economic Growth - Standard Model of Trade and Economic Growth - Kaldors Theory of Export Led Growth - Prebisch and Singer Effects - Terms of Trade – Trade and income distribution.

Unit V: Trade Policy Applications

Markets for foreign exchange - Exchange rates – Balance of Payment, FDI and Exchange Rate relationships – Prices adjustment and exchange rate determination - fixed/ flexible exchange rate regime – Recent events in IMF relations. - Agri. Export Policy of India.

PRACTICALS

Welfare analysis of trade – Direction and Pattern of trade - Gravity Models - Introduction to partial and general equilibrium models - Analyzing the effect of trade policies both under Partial and General Equilibrium cases-- Empirical estimation of Partial and General Equilibrium Models of Trade - Application of Multi-market and CGE Models to trade - Standard Model of Trade and Economic Growth - Exchange Rate determination under fixed / flexible exchange rate regime. RTA/ FTA analysis.

LECTURE SCHEDULE	
1	Classical Theory of trade revisited – causes for nations to trade
2	Welfare implications under different trade models
3	Contributions by New Trade Theory – scope and implications
4	General equilibrium analysis under open & closed economy
5	Factor mobility and international trade
6	Imperfect competition & returns to scale – trade implications
7	Trade protective measures – impact of tariff measures
8	Trade protective measures – impact of non-tariff measures
9	Trade blocks – impact of RTA/ FTA – case studies
10	Trade creation & trade diversion – direction of trade
11	Terms of trade & income distribution
12	Models of Trade & economic growth - arguments
13	Demand & supply of foreign exchange
14	Balance of Payments, Foreign Direct Investment & exchange rate relationships
15	Trends in IMF relations
16	Impact of WTO agreements
PRACTICAL SCHEDULE	
1	Welfare analysis under open & closed economy
2	Direction of trade – Constant Market Share (CMS) approach
3	Direction of trade – Gravity trade models
4	Tariff implications on small country assumptions
5	Tariff implications on large country assumptions
6	Welfare implications under classical trade models
7	Welfare implications under new trade models
8	Effect of trade policies – partial equilibrium setting – I
9	Effect of trade policies – partial equilibrium setting – II
10	Effect of trade policies – general equilibrium setting – I
11	Effect of trade policies – general equilibrium setting – II
12	Terms of trade & income estimation
13	Exchange rate determination – fixed regime
14	Exchange rate determination – flexible regime
15	Empirical estimation of FDI, BoP & exchange rate relationships
16	Empirical estimation of RTA/FTA
17	**Final practical examination**
SUGGESTED READINGS	

1	Dennis R. Apple yard and Alfred J. Field Jr. 1995, International Economics – Trade, Theory and Policy, (Chicago: Irwin).
2	James P.Houck, 1992. Elements of Agricultural Trade Policies, (Wave Land Press, Inc, Illinois)
3	Miltiades Chacholiades, 1985. International Trade Theory and Policy, (McGraw-Hill Book Company, London).
4	Feenstra C.Robert.2006. Advanced International Trade: Theory and Evidences. Princeton, NJ. Princeton University Press.
5	Krugman, Paul and Maurice Obstfeld. 2003. International Economics: Theory and Policy. 6th Edition. Boston,MA: Addison Wesley.

SUGGESTED WEBSITES	
1	http://internationalecon.com/Trade/Tch5/Tch5.php
2	http://ocw.mit.edu/courses/economics/14-581-international-economics-i-spring-2013/
3	http://catalog.flatworldknowledge.com/catalog/editions/suranovic-international-economics-theory-and-policy-1-0

OUTCOME EXPECTED
After successful completion of the course, the student will be able to understand how trade theories influence the existing pattern of international trade, factor use and trade competitiveness and associated consequences.

Ph.D. Agronomy

Ph.D. Agronomy

Sl No.	Course code	Course Title	Cr. Hr.
I.	**Major courses (12 credits)**		
01	Agron 601*	Current trends in Agronomy	3+0
02	Agron 602	Recent trends in crop growth and productivity	2+1
03	Agron 603	Irrigation management	2+1
04	Agron 604	Recent trends in weed management	2+1
05	Agron 605	Integrated farming systems for sustainable Agriculture	2+0
06	Agron 606	Soil Conservation and Watershed Management	2+1
07	Agron 607	Stress Crop Production	2+1
08	Agron 608*	Research and Publication ethics	2+0
II.	**Minor Courses (6 credits)**		
01.	AGM 601	Climate Change and Sustainable Development	2+1
III.	**Supporting Courses (5 credits)**		
IV.	**Seminar (2 credits)**		
01	Agron 691	Doctoral Seminar	0+1
02	Agron 692	Doctoral Seminar	0+1
V.	**Thesis Research (75 credits)**		
01	Agron 699	Doctoral Research	0+75

* Courses to be compulsorily registered

Agron 601 Current Trends in Agronomy 3+0

AIM OF THE COURSE

To acquaint the students about recent advances in agricultural production.

THEORY

Unit I

Globalization of agriculture and WTO, global warming, GM crops, Conservation agriculture: principles, prospects and importance, potential benefits of CA under climate change scenario, policy issues.

Unit II

Agro-physiological and environmental basis for variation in yield, recent advances in soil-plant-water relationship

Unit III

Precision farming: GIS, GPS and remote sensing for crop management, Mechanization in crop production: modern agricultural precision tools and technologies, Contract farming, Organic farming: marketing and export potential of organic products, certification, labelling and accreditation procedures in organic farming.

Unit IV

Crop residue management in multiple cropping systems; weed management, cropping systems, grassland management, agro-forestry, allelopathy, seed production technologies; seed certification, seed multiplication, hybrid seed production.

Unit V

Concepts of system agriculture; holistic approach of farming systems, dryland farming, sustainable agriculture and research methodology in Agronomy; bio-physical models for crop and cropping system simulation.

LECTURE SCHEDULE

1. Globalization of Agriculture
2. WTO – History, location and co-operation with other organizations
3. Role and importance of WTO in agriculture
4. Global warming – Meaning, Causes, green house gases,
5. Global warming – ill effects of global warming, effect on yield of crops, Remedies to reduce global warming.
6. GM crops – Meaning, Need for GM crops, Advantages and limitation, Methods of producing GM crops.
7. GM crops – Food safety and environmental issues
8. Conservation agriculture – meaning, principles, prospects and importance
9. Conservation agriculture – potential benefits of CA under climate change scenario, policy issues.
10. Agro-physiological basis for variation in yield
11. Environmental basis for variation in yield
12. Soil-plant-water relationship

13. Recent advances in soil-plant-water relationship
14. Precision farming – Concept, adaptability, advantages and limitations
15. GIS, GPS and remote sensing for crop management.
16. Mechanization in crop production
17. Modern agricultural precision tools and technologies
18. Contract farming – Meaning, Scope, Suitability, advantages and limitations
19. Organic farming – Meaning, Scope, Suitability, advantages and limitations
20. Marketing and export potential of organic products
21. Certification, labelling and accreditation procedures in organic farming.
22. Crop residue management – importance, availability, estimation of nutrient availability from crop residues
23. Crop residue management in multiple cropping systems
24. Weed management – Methods of weed management; weed prevention
25. Weed management – Physical, cultural, chemical and integrated weed management
26. Weed management in cropping systems
27. Cropping systems – Meaning/concepts, different cropping systems
28. Estimating yield advantage in cropping systems
29. Grassland management
30. Agro-forestry – meaning, methods, advantages and limitations
31. Allelopathy – meaning, history, applications in crop production
32. Seed production technologies
33. Seed certification and seed multiplication
34. Hybrid seed production
35. System agriculture – concepts
36. Holistic approach of farming systems
37. Farming systems for wetlands
38. Farming systems for garden lands
39. Farming systems for drylands
40. Dryland farming – meaning, area under dryland farming in India, Soil and water conservation techniques
41. Crop production techniques of for higher productivity in dryland conditions
42. Sustainable Agriculture – meaning, advantages and limitations
43. Sustainable Agriculture practices
44. Research methodology in Agronomy
45. Different statistical designs for agronomic research
46. Recording biometric observations
47. Bio-physical models for crop and cropping system simulation

LEARNING OUTCOME

Recent advances in agricultural production

SUGGESTED READING

Agarwal RL. 1995. *Seed Technology*. Oxford & IBH.

Dahiya BS and Rai KN. 1997.*Seed Technology*. Kalyani.

Govardhan V. 2000.*Remote Sensing and Water Management in Command Areas: Agroecological Prospectives*. IBDC.

Narasaiah ML. 2004.*World Trade Organization and Agriculture*. Sonali Publ.

Palaniappan SP and Annadurai K. 2006.*Organic Farming - Theory and Practice*. Scientific Publ.

Sen S and Ghosh N. 1999.*Seed Science and Technology*. Kalyani.

Tarafdar JC, Tripathi KP and Kumar M. 2007.*Organic Agriculture* Scientific Publ.

Kumar, R, Swarnkar KS, Singh KS and Narayan S. 2016.*A Text Book of Seed Technology*. Kalyani Publication.

Reddy SR and Prabhakara G. 2015.*Dryland Agriculture*. Kalyani Publishers.

Gururajan B, Balasubhramanian R and Swaminath V. 2013.*Recent Strategies on Crop Production*. Kalyani Publishers.

Venkateswarlu B and Shanker Arun K. 2009.*Climate change and agriculture: Adaptation and mitigation strategies*. *Indian Journal of Agronomy* **54**(2): 226-230.

Muhammad Farooq and K.H. M. Siddique. 2019. Conservation Agriculture. DOI https://doi.org/10.1007/978-3-319-11620-4

Somasundaram Jayaraman, Ram C. Dalal, Ashok K. Patra, Suresh K. Chaudhari. 2021. Conservation Agriculture: A Sustainable Approach for Soil Health and Food Security Conservation Agriculture for Sustainable Agriculture. Springer Publications.

Agron 602 Recent Trends in Crop Growth and Productivity 2+1

AIM OF THE COURSE

To study the physiology of vegetative and reproductive growth in relation to productivity of different crops in various environments.

THEORY

Unit I

Plant density and crop productivity; plant and environmental factors, yield, plant distribution, strategies for maximizing solar energy utilization; leaf area – Different methods of estimation; interception of solar radiation and crop growth;

Unit II

Photosynthesis: the photosynthetic apparatus, factors essential for photosynthesis; difference in photosynthetic rates among and within species; physiological limitations to crop yield; solar radiation concept and agro-techniques for harvesting solar radiation.

Unit III

Growth analysis: concept, CGR, RGR, NAR, LAI, LAD, LAR; validity and Limitations, in interpreting crop growth and development; growth curves: sigmoid, polynomial, and asymptotic; root systems; root-shoot relationship; principles involved in inter and mixed cropping systems under rainfed and irrigated conditions; concept and differentiation of inter and mixed cropping; criteria in assessing the yield advantages.

Unit IV

Competitive relationship and competition functions; biological and agronomic basis of yield advantage under intercropping; physiological principles of dry land crop production, constraints and remedial measures; heat unit concept of crop maturity: concept and types of heat units.

Unit V

Concept of plant ideotypes: crop physiological and new ideotypes; characteristics of ideotype for wheat, rice, maize, etc.; concept and types of growth hormones; their role in field crop production; efficient use of resources.

PRACTICAL

- Field measurement of root-shoot relationship in crops at different growth stages
- Estimation of growth evaluating parameters like CGR, RGR, NAR, LAI etc., at different stages of crop growth
- Computation of harvest index of various crops
- Assessment of crop yield on the basis of yield attributing characters
- Construction of crop growth curves based on growth analysis data
- Computation of competition functions, viz. LER, IER aggressivity competition index, etc in intercropping
- Senescence and abscission indices
- Analysis of productivity trend in un-irrigated areas
- Analysis of productivity trend in irrigated areas

THEORY LECTURE SCHEDULE

1. Plant density and crop productivity
2. Plant and environmental factors
3. Yield
4. Plant distribution
5. Strategies for maximizing solar energy utilization
6. Leaf area- Different methods of estimation
7. Interception of solar radiation and crop growth
8. Photosynthesis - the photosynthetic apparatus
9. Factors essential for photosynthesis
10. Difference in photosynthetic rates among and within species
11. Physiological limitations to crop yield
12. Solar radiation concept and agro-techniques for harvesting solar radiation
13. Growth analysis: concept, validity and limitations in interpreting crop growth and development of CGR, RGR and NAR
14. Growth analysis: concept, validity and limitations in interpreting crop growth and development of LAI, LAD and LAR
15. Growth curves: sigmoid, polynomial, and asymptotic
16. Root systems; root-shoot relationship
17. Principles involved in inter and mixed cropping systems under rainfed and irrigated conditions
18. Concept and differentiation of inter and mixed cropping
19. Criteria in assessing the yield advantages.
20. Competitive relationship and competition functions
21. Biological and agronomic basis of yield advantage under intercropping
22. Physiological principles of dry land crop production
23. Constraints in dryland crop production
24. Remedial measures in dryland crop production
25. Heat unit concept of crop maturity - concept and types of heat units
26. Concept of plant ideotypes
27. Crop physiological and new ideotypes
28. Characteristics of ideotype for wheat, rice, maize, etc
29. Concept and types of growth hormones
30. Role of growth hormones in field crop production
31. Efficient use of resources

PRACTICAL SCHEDULE

1. Field measurement of root-shoot relationship in rice at different growth stages
2. Field measurement of root-shoot relationship in maize at different growth stages
3. Field measurement of root-shoot relationship in pulses (Black gram/green gram) at different growth stages
4. Estimation of growth evaluating parameters like CGR, RGR, NAR, LAI etc., at different stages of rice

5. Estimation of growth evaluating parameters like CGR, RGR, NAR, LAI etc., at different stages of maize
6. Estimation of growth evaluating parameters like CGR, RGR, NAR, LAI etc., at different stages of pulses (Black gram/green gram)
7. Assessment of crop yield on the basis of yield attributing characters in rice
8. Assessment of crop yield on the basis of yield attributing characters in pulses
9. Computation of harvest index of rice
10. Computation of harvest index of maize
11. Computation of harvest index of pulses
12. Construction of crop growth curves based on growth analysis data
13. Computation of competition functions, *viz*. LER, IER, aggressivity competition index, etc. in intercropping
14. Senescence and abscission indices
15. Analysis of productivity trend in un-irrigated areas
16. Analysis of productivity trend in irrigated areas
17. **PRACTICAL EXAMINATION**

LEARNING OUTCOME

Experience on the knowledge of crop growth for agricultural production

SUGGESTED READING

Chopra VL and Paroda RS. 1984. Approaches for Incorporation of Drought and Salinity Resistance in Crop Plants. Oxford & IBH.

Delvin RM and Vitham FH. 1986. Plant Physiology. CBS Publ.

Evans LT. 1975. Crop Physiology.Cambridge Univ. Press.

Evans LT. 1996. Crop Evolution, Adaptation and Yield.Cambridge Univ. Press.

Gupta US. (Ed.). 1995. Production and Improvement of Crops for Drylands. Oxford & IBH.

Gupta US. 1988. Progress in Crop Physiology. Oxford & IBH.

Kramer PJ and Boyer JS. 1995. Water Relations of Plant and Soils. Academic Press.

Mukherjee S and Ghosh AK. 1996. Plant Physiology. Tata McGraw Hill.

Narwal SS, Politycka B and Goswami CL. 2007. Plant Physiology: Research Methods. Scientific Pub.

Tiaz L. and Zeiger E. 2006. Plant Physiology. Sinauer Associates, Inc.

Agron 603 Irrigation Management 2+1

AIM OF THE COURSE

To teach students about optimization of irrigation in different crops under variable agro climatic conditions.

THEORY

Unit I

Global water resources; Water resources of India, irrigation projects during pre- and post-independence period and their significance in crop production. Soil and plant water potential; Soil-plant-water atmospheric relationships, evaporation, transpiration and evapotranspiration, significance of transpiration, energy utilization in transpiration, physiological processes and crop productivity. Factors affecting ET, control of ET by mulching and use of anti-transpirants. Infiltration – water movement in soil under saturated and unsaturated conditions. Poiseulle's and Darcy's law, general equation of saturated and unsaturated flow of water in soil.

Unit II

Water requirement; water use efficiency and management practices to improve water use efficiency of crops. Crop water stress, water deficit and crop growth, adaptability of the crops. Fertilizer use in relation to irrigation. Water availability and its relation to nutrient availability.

Unit III

Conventional methods of irrigation, advanced irrigation methods, management of water in controlled environments and polyhouses. Automated irrigation system.

Unit IV

Strategies of using limited water supply; optimizing the use of given irrigation supplies; cop planning for optimum use of irrigation water. Ground water utilization and its impact on crop production. Drainage. Management of poor quality water. Water production function, Modelling in irrigation water management, economic analysis of irrigation.

Unit V

Land suitability for irrigation, land irrigability classification; conveyance and distribution system in irrigation projects, irrigation efficiency; agronomic considerations in the design and operation of irrigation projects; characteristics of irrigation and farming systems affecting irrigation management, integrated water management in command areas, water management institutions in commands, farmer's participation in command areas; irrigation legislation.

PRACTICAL

1. Determination of water infiltration characteristics of soil profiles
2. Determination of water holding capacity of soil profiles
3. Study of moisture extraction pattern in various crops.
4. Determination of ET / PET.
5. Determination of crop co-efficient of important crop (Sesame/black gram/green gram).
6. Estimation of soil moisture balance.
7. Designing, layout and evaluation of drip irrigation and working out the water requirement.

8. Designing, layout and evaluation of sprinkler irrigation and working out the water requirement.
9. Working out irrigation efficiencies.
10. Determination of irrigation timing under different methods of irrigation.
11. Working out economics of irrigations systems.
12. Determination of consumptive use and water requirement of a given cropping pattern.
13. Designing of drainage channel.
14. Water quality analysis and management of poor quality irrigation water.
15. Irrigation management modelling studies
16. Visit to irrigation command area / irrigation automation farms in farmers' field.

LECTURE SCHEDULE

1. Water resources of World and India. Availability of water resources for different sectors in India. Projections for next 25 years. Area and crop irrigated in India,
2. Irrigation - Definition, Irrigation projects during pre-post-independence period in India and their significance in crop production
3. Soil and plant water potential. Soil moisture constants and their importance in irrigation.
4. Soil-plant-water atmospheric relationships – evaporation, transpiration, ET and potential evapotranspiration. Significance of transpiration, transpiration efficiency - transpiration co-efficient, energy utilization in transpiration, physiological processes and crop productivity.
5. Factors affecting ET and crop yield. Control of ET by mulching and use of anti-transpirants.
6. Infiltration – Definition. Water movement in soil under saturated and unsaturated conditions. Water vapour movement. Poiseulle's and Darcy's law, general of saturated and unsaturated flow of water in soil.
7. Crop water requirement for various agricultural crops - Factors affecting crop water requirement. Critical stages of water requirement for different agricultural crops.
8. Crop water requirement for various horticultural crops. Critical stages of water requirement for different horticultural crops.
9. Water use efficiency and management practices to improve water use efficiency of crops.
10. Crop water stress, water deficit and crop growth, adaptability of the crops and measures to overcome moisture stress.
11. Fertilizer use in relation to irrigation. Water availability and its relation to nutrient availability.
12. Methods of irrigation – conventional methods of irrigation.
13. Methods of irrigation – Overhead and micro-irrigation - sprinkler irrigation - suitability - components - operations - advantages and disadvantages
14. Drip irrigation - suitability - components - layout - operation - advantages and disadvantages
15. Special and advanced methods of irrigation - suitability and advantages, deficit irrigation, automated irrigation system
16. Concept of fertigation- fertilizer type - suitability - method of applying fertilizer through irrigation water - fertigation under sub surface method
17. Irrigation under controlled environment - glass houses - green house - poly house – netted house - pot watering - sprinkling - pipe irrigations

18. Strategies of using limited water supply; optimizing the use of given irrigation supplies. Crop planning for optimum use of irrigation water.
19. Ground water utilization and its impact on crop production. Ground water recharge - definition, sea water intrusion, sea water utilization
20. Drainage and its importance. Causes and ill effects of excess water on soil and plants - tolerance of plants for water stagnated environment.
21. Methods of draining water - surface and subsurface methods; layout-drainage requirement for different crops.
22. Quality of Irrigation water. Management of poor quality water.
23. Water production function
24. Modelling in irrigation water management.
25. Economic analysis of irrigation
26. Land suitability for irrigation. Land irrigability classification.
27. Conveyance and distribution system in irrigation projects. Irrigation efficiency; agronomic considerations in the design and operation of irrigation projects
28. Characteristics of irrigation and farming systems affecting irrigation management.
29. Integrated water management in command areas. Institution of water management in command areas
30. Farmer's participation in command areas.
31. Irrigation legislation.

PRACTICAL SCHEDULE

1. Determination of water infiltration characteristics of soil profiles
2. Determination of water holding capacity of soil profiles
3. Study of moisture extraction pattern in various crops.
4. Determination of ET/PET
5. Determination of crop co-efficient of important crop (Sesame/black gram/green gram).
6. Estimation of soil moisture balance.
7. Designing, layout and evaluation of drip irrigation and working out the water requirement.
8. Designing, layout and evaluation of sprinkler irrigation and working out the water requirement.
9. Working out irrigation efficiencies.
10. Determination of irrigation timing under different methods of irrigation.
11. Working out economics of irrigations systems.
12. Determination of consumptive use and water requirement of a given cropping pattern.
13. Designing of drainage channel.
14. Water quality analysis and management of poor quality irrigation water.
15. Irrigation management modelling studies
16. Visit to irrigation command area / irrigation automation farms in farmers' field.
17. **FINAL PRACTICAL EXAMINATION**

LEARNING OUTCOME

Experience on the knowledge of crop growth for agricultural production

SUGGESTED READINGS

Panda S.C. 2003. *Principles and Practices of Water Management*. Agrobios Pub.

Singh MP, 2017. *Recent advances in Irrigation water management*. Kalyani Publishers

FAO, 1984. *Irrigation Practice and Water Management*. Oxford & IBH.

Mishra RR and Ahmad M. 1987. *Manual on Irrigation and Agronomy*. Oxford & IBH

Reddy S.R. 2000. *Principles of Crop Production*. Kalyani publishers.

Sankara Reddy GH and Yellamananda Reddy. 1995. *Efficient Use of Irrigation Water*. In: Gupta US. (Ed.). Production and Improvement of Crops for Drylands. Oxford & IBH

Lenka D. 1999. Irrigation and Drainage. Kalyani publishers.

Michael AM. 1978. Irrigation: Theory and Practice. Vikas Publ.

Majumdar DK. 2014. Irrigation Water Management: Principles and Practice. PHI publishers.

Mukund Joshi. 2013. A Text book of Irrigation and Water Management. Kalyani publishers.

Agron 604 Recent Trends in Weed Management 2+1

AIM OF THE COURSE

To teach about the changing weed flora, new herbicides, their resistance, toxicity, antidotes and residue management under different cropping systems.

THEORY

Unit I

Crop-weed competition in different cropping situations; changes in weed flora, various causes and effects; different methods of weed management. Migration, introduction, adaptation of weeds. Invasive weeds - Different mechanisms of invasion — present status and factors influencing weed invasion. Biology and management.- Parthenium, Lantana, Chromolaena, Water hyacinth and Mikania.

Unit II

Physiological and biological aspects of herbicides, their absorption. translocation, metabolism and mode of action; selectivity of herbicides and factors affecting them.

Unit III

Climatic factors and phytotoxicity of herbicides: fate of herbicides in soil and factors affecting them, Degradation of herbicides in soil and plants- factors affecting it, primary and secondary metabolites, residue management of herbicides, adjuvants- Concepts and examples

Unit IV

Advances in herbicide products and application techniques and methods; herbicide resistance-Types- major HR weeds; antidotes and crop protection compatibility of herbicides of different groups; compatibility of herbicides with other pesticides: herbicide rotation and herbicide mixtures. Development of transgenic herbicide resistant crops: herbicide development, registration procedures.- Important herbicides registered for field crops in India

Unit V

Relationship of herbicides with tillage, fertilizer, and irrigation, cropping system; bioherbicides, allelochemical and alleloherbicides, herbicide bioassays. Nanotechnology in herbicidal weed management. Recent advances in nonchemical weed management. including deleterious rhizobacteria, biodegradable film, robotics and drones.

PRACTICAL

Crop-weed competition in lowland and upland ecosystem. Biology and management of lowland and upland weed. Weed seedbank estimation studies. Role of allelopathy in weed management. Herbicide spray calibration and methods of testing of herbicides (greenhouse and field condition). Drone technology in herbicide application. Study of adjuvants and antidotes on weed management. Bioassay of herbicides, Herbicide resistance studies. Nanotechnology in herbicidal weed management. Visit and estimate herbicide residue. Visit to agro-chemical industry.

LECTURE SCHEDULE

1. Crop-weed competition in different cropping situations
2. Changes in weed flora, various causes and effects
3. Different methods of weed management

4. Migration, introduction, adaptation of weeds
5. Invasive weeds- Different mechanisms of invasion — present status
6. Factors influencing weed invasion
7. Biology and management- Parthenium and Lantana,
8. Biology and management- Chromolaena, water hyacinth and Mikania
9. Herbicides- Physiological and biological aspects
10. Absorption and translocation of herbicides
11. Metabolism and mode of action of herbicides
12. Herbicides selectivity and factors affecting herbicide selectivity
13. Climatic factors affecting herbicide selectivity
14. Phytotoxicity of herbicides
15. Fate of herbicides in soil- influencing factors
16. Degradation of herbicides in soil and plants- factors influencing it
17. Primary and secondary metabolites
18. Residue management of herbicides
19. Adjuvants- Concepts and examples
20. Advances in herbicide products
21. Herbicide application techniques and methods
22. herbicide resistance -Types and major herbicide resistant weeds
23. Development of transgenic herbicide resistant crops
24. Antidotes and crop protection; compatibility of herbicides with other pesticides
25. Herbicide rotation and herbicide mixtures
26. Herbicide development, registration procedures- Important herbicides registered for field crops in India
27. Relationship of herbicides with tillage and fertilizer, irrigation and cropping system.
28. Bioherbicides, allelochemical and alleloherbicides.
29. Herbicide bioassays
30. Nanotechnology in herbicidal weed management.
31. Recent advances in nonchemical weed management- deleterious rhizobacteria and biodegradable film, robotics and drones

PRACTICAL SCHEDULE

1. Study on crop-weed competition in lowland ecosystem
2. Study on crop-weed competition in upland ecosystem
3. Study on biology and management of lowland weed
4. Study on biology and management of upland weed
5. Study on weed seedbank estimation
6. Study on allelopathy for weed management
7. Study on herbicide spray calibration
8. Study on methods of testing of herbicides
9. Study on herbicide application with drones
10. Study on adjuvants in weed management

11. Study on antidotes for crop protection
12. Study on herbicide bioassay
13. Study on herbicide resistance in weeds
14. Study on nano herbicide in weed management
15. Visit to residue laboratory and estimation of herbicide residue
16. Visit to agro-chemical unit/ industry
17. **FINAL PRACTICAL EXAMINATION**

LEARNING OUTCOME

Experience on the knowledge of new herbicides, their resistance, toxicity, antidotes, and residue management under different cropping systems.

SUGGESTED READING

Böger, Peter, Wakabayashi, Ko, Hirai, Kenji (Eds.). 2002. *Herbicide Classes in Development. Mode of Action, Targets, Genetic Engineering, Chemistry.*Springer.

Das TK. 2013. *Weed Science: Basics and Applications*, Jain Brothers (New Delhi)

Fennimore, Steven A and Bell, Carl. 2014. *Principles of Weed Control*, 4th Ed, California Weed Sci. Soc.

Gupta OP. 2007. *Weed Management: Principles and Practices*, 2nd Ed.

Jugulan M, (ed). 2017. *Biology, Physiology and Molecular Biology of Weeds*. CRC Press

Monaco TJ, Weller SC and Ashton FM. 2014. *Weed Science Principles and Practices*, Wiley

Powles SB and Shaner DL. 2001. *Herbicide Resistance and World Grains*, CRC Press.

Walia US. 2006. *Weed Management*, Kalyani.

Zimdahl RL. (ed). 2018. *Integrated Weed Management for Sustainable Agriculture, B. D. Sci. Pub*

SUGGESTED WEBSITES

https://isws.org.in/IJWSn/Journal.aspx
https://onlinelibrary.wiley.com/journal/13653180
https://www.cambridge.org/core/journals/weed-science
https://dwr.icar.gov.in/
https://wssa.net/

Agron 605 Integrated Farming Systems for Sustainable Agriculture 2+0

AIM OF THE COURSE

To appraise about different enterprises suitable for different agroclimatic conditions for sustainable agriculture.

THEORY

Unit I

Sustainable agriculture: Introduction, definition, concepts and goals; Elements of sustainability; Status of sustainable agriculture in India; Concept of sustainability in Integrated farming systems; Integrated Farming systems (IFS): definition, scope and importance.

Unit II

Classification of IFS based on enterprises as well as under rainfed/ irrigated condition in different land situation, farming systems according to type of rotation, intensity of rotation, degree of commercialization, water supply, enterprises. Efficient Integrated farming systems based on economic viability and natural resources - identification and management.

Unit III

Production potential of different components of Integrated farming systems; interaction and mechanism of different production factors; stability of Integrated Farming system based on research/ long term information in different systems through research; Integration of components and adaptability of different farming system based on land situations and climatic condition of a region; evaluation of IFS.

Unit IV

Eco-physiological approaches to intercropping; soil nutrient management in intercropping; Simulation models for intercropping; preparation of different farming system models; evaluation of different farming systems. Formation of different Integrated Farming system Models; evaluation of different Integrated Farming system models. Recycling of organic waste in IFS.

Unit V

New concepts and approaches of farming system and organic farming; value addition, waste recycling, quantification and mitigation of Green House gases; case studies/ success stories of different Integrated Farming systems, cropping systems and organic farming; case studies on different farming systems. Possible use of ITK in Integrated farming system.

LECTURE SCHEDULE

1. Sustainable agriculture: Introduction, definition, concepts and goals
2. Elements of sustainability and Status of sustainable agriculture in India
3. Concept of sustainability in Integrated farming systems
4. Integrated Farming systems (IFS): definition, scope and importance
5. Classification of IFS based on enterprises
6. Classification of IFS under rainfed/ irrigated condition in different land situation
7. Farming systems according to type of rotation and intensity of rotation
8. Farming systems according to degree of commercialization and water supply

9. Farming systems according to enterprises.
10. Efficient Integrated farming systems based on economic viability
11. Efficient Integrated farming systems based on natural resources
12. Identification and management of efficient Integrated farming systems
13. Production potential of different components of Integrated farming systems
14. Interaction and mechanism of different production factors
15. Stability of Integrated Farming system based on research/ long term information in different systems through research
16. Integration of components in IFS
17. Adaptability of different farming system based on land situations and climatic conditions of a region
18. Evaluation of IFS.
19. Eco-physiological approaches to intercropping.
20. Soil and nutrient management in intercropping
21. Simulation models for intercropping
22. Preparation of different farming system models
23. Evaluation of different farming systems models
24. Formation of different Integrated Farming system Models
25. Evaluation of different Integrated Farming system models
26. New concepts and approaches of farming system and organic farming
27. Value addition and waste recycling
28. Quantification and mitigation of Green House gases
29. Case studies/ success stories of different Integrated Farming systems, Cropping systems and organic farming
30. Case studies on different farming systems.
31. Possible use of ITK in Integrated farming system.

LEARNING OUTCOME

Experience on the knowledge of enterprises suitable for different agroclimatic conditions for sustainable agriculture and their proper utilization.

SUGGESTED READING

Ananthakrishnan TN. (Ed.). 1992. Emerging Trends in Biological Control of *Phytophagus Insects.* Oxford & IBH

Baishya A, Borah M, Das AK, Hazarika J, Gogoi B and Borah AS 2017. *Waste recycling through Integrated Farming systems. An Assam Agriculture Experience*. Omni Scriptum Gmbh& Co. KG, Germany.

Balasubramanian P and Palaniappan SP. 2006. *Principles and Practices of Agronomy*. Agrobios.

Edens T. 1984. *Sustainable Agriculture and Integrated Farming System*. Michigan State Univ. press.

Jayanthi C. 2006. *Integrated Farming systems- A way to sustainable Agriculture*. Tamil Nadu Agricultural University, Coimbatore.

Joshi M and Parbhakarasetty TK. 2005. *Sustainability through Organic Farming*. Kalyani Publ.

Kolhapure A and Madhukar D. *A Text Book of Farming System And Sustainable Agriculture.*

Palaniappan SP and Anandurai K. 1999. *Organic Farming - Theory and Practice.* Scientific Publ.

Panda SC. 2004. *Cropping systems and Farming Systems*. AgrobiosPubl..

Lampin N. 1990. *Organic Farming*. Farming Press Books.

Ravisankar D and Jayanthi C. 2015. *Farming systems: concepts and approaches*. Agrobios publ.

Agron 606 Soil Conservation and Watershed Management 2+1

AIM OF THE COURSE

To teach about different soil moisture conservation technologies for enhancing the agricultural productivity through holistic

THEORY

Unit I

Soil erosion: definition, nature and extent of erosion; types of erosion, factors affecting erosion. Water erosion – Forms and mechanism; extent of soil loss. Wind erosion – Forms and mechanism; extent of soil loss

Unit II

Soil conservation: definition, methods of soil conservation; agronomic measures - contour cultivation, strip cropping, cover crops; mulching, tillage, cropping system vegetative barriers; improved dry farming practices; mechanical measures - bunding, gully control, bench terracing; role of grasses and pastures in soil conservation; wind breaks and shelter belts.

Unit III

Watershed management: definition, objectives, concepts, approaches, components, steps in implementation of watershed; development of cropping systems for watershed areas. Watershed development programmes in India.

Unit IV

Agro ecological classification; Land use capability classification, alternate land use systems; agro-forestry; ley farming; *jhum* management - basic concepts, socio-ethnic aspects, its layout.

Unit V

Drainage – methods of drainage, Drainage considerations and agronomic management; rehabilitation of abandoned *jhum* lands and measures to prevent soil erosion.

PRACTICAL

- Study of different types of erosion
- Determination of dispersion ratio
- Estimation of soil loss by Universal Soil Loss Equation
- Estimation of soil loss by wind erosion
- Measurement of runoff and soil loss
- Field studies of different soil conservation measures
- Laying out run-off plot and deciding treatments
- Identification of different grasses and trees for soil conservation
- Visit to watershed areas
- Visit to a soil conservation research centre, demonstration and training centre

LECTURE SCHEDULE

1. Soil erosion: definition, nature and extent of erosion
2. Types of erosion, factors affecting erosion and losses due to erosion
3. Water erosion – Forms and mechanism; extent of soil loss

4. Wind erosion – Forms and mechanism; extent of soil loss
5. Soil conservation: definition, methods of soil conservation
6. Agronomic measures - contour cultivation, strip cropping, cover crops
7. Agronomic measures - Mulching, tillage, cropping system, vegetative barriers
8. Improved dry farming practices
9. Mechanical measures - bunding, gully control, bench terracing
10. Role of grasses and pastures in soil conservation
11. Control measures for wind erosion
12. Wind breaks and shelter belts
13. Watershed management: definition, objectives, concepts
14. Approaches of watershed management
15. Components of watershed management
16. Steps in implementation of watershed
17. Development of cropping systems for watershed areas
18. Watershed development programmes in India
19. Agro ecological classification
20. Land use capability classification
21. Alternate land use systems
22. Agro-forestry – Types
23. Role of Agroforestry in watershed management
24. Ley farming
25. Jhum management - basic concepts, socio-ethnic aspects, its layout.
26. Rehabilitation of abandoned jhum lands
27. Measures to prevent soil erosion
28. Drainage – Definition, its necessity and effect on crops and soil
29. Methods of drainage – Surface methods
30. Methods of drainage – sub surface methods
31. Drainage considerations and agronomic management

PRACTICAL SCHEDULE

1. Study of different types of erosion
2. Determination of dispersion ratio
3. Computation of rainfall erosivity index
4. Computation of soil erodibility index
5. Estimation of land slope
6. Estimation of soil loss by Universal Soil Loss Equation
7. Laying out run-off plot and deciding treatments
8. Measurement of runoff and soil loss
9. Estimation of soil loss by wind erosion
10. Field studies of different soil conservation measures
11. Identification of different grasses and trees for soil conservation
12. Prioritization of watershed using remote sensing and GIS

13. Delineation and codification of watersheds in India
14. Studies on methods of farm drainage
15. Visit to watershed areas
16. Visit to a soil conservation research centre, demonstration and training centre
17. **PRACTICAL EXAMINATION**

LEARNING OUTCOME

Experience on the knowledge of soil moisture conservation technologies for enhancing the agricultural productivity through holistic approach watershed management.

SUGGESTED READING

Arakeri HR and Roy D. 1984. *Principles of Soil Conservation and Water Management*. Oxford & IBH.

Dhruvanarayana VV. 1993. *Soil and Water Conservation Research in India*. ICAR.

FAO. 2004. *Soil and Water Conservation in Semi-Arid Areas. Soils Bull.,* Paper 57.

Frederick RT, Hobbs J, Arthur D and Roy L. 1999. *Soil and Water Conservation: Productivity and Environment Protection.* 3rd Ed. Prentice Hall.

Gurmel Singh, Venkataraman CG, Sastry B and Joshi P. 1990. *Manual of Soil and Water Conservation Practices.* Oxford & IBH.

Murthy VVN. 1995. *Land and Water Management Engineering*. Kalyani.

Tripathi RP and Singh HP. 1993. *Soil Erosion and Conservation*. Wiley Eastern.

Yellamanda Reddy T and Sankara Reddy GH. 1992. *Principles of Agronomy*. Kalyani Publ.

Agron 607 Stress Crop Production 2+1

AIM OF THE COURSE

To study various types of stresses in crop production and strategies to overcome them.

THEORY

Unit I

Stress and strain terminology; nature and stress injury; susceptibility and resistance to stress; causes of stress.

Unit II

Low temperature stress: freezing injury and resistance in plants, measurement of freezing tolerance, chilling injury and resistance in plants, practical ways to overcome the effect of low temperature tress through, soil and crop manipulations. High temperature or heat stress: meaning of heat stress, heat injury and resistance in plants, practical ways to overcome the effect of heat stress through soil and crop manipulations.

Unit III

Water deficit stress: meaning of plant water deficient stress and its effect on growth and development, water deficit injury and resistance, practical ways to overcome effect of water deficit stress through soil and crop, manipulations. Excess water or flooding stress: meaning of excess water stress, its kinds and effects on crop plants, excess water stress injury and resistance, practical ways to overcome excess water stress through soil and crop manipulations.

Unit IV

Salt stress: meaning of salt stress and its effect on crop growth, salt stress injury and resistance in plants, practical ways to overcome the effect of salt stress through soil and crop manipulations.

Unit V

Mechanical impedance of soil and its impact on plant growth; measures to overcome soil mechanical impedance. Environmental pollution: air, soil and water pollution, and their effect on crop growth and quality of produce; ways and means to prevent environmental pollution.

PRACTICAL

- Determination of electrical conductivity of plant cell sap
- Determination of osmotic potential and tissue water potential
- Measurement of transpiration rate
- Measurement of stomatal frequency
- Measurement of Relative Water Content of leaf
- Measurement of electrolytic leakage
- Growing of plants in sand culture under salt stress for biochemical and physiological studies
- Studies on effect of osmotic and ionic stress on seed germination and seedling growth
- Measurement of low temperature injury under field conditions
- Studies on plant responses to excess water.

LECTURE SCHEDULE

1. Stress and strain – terminology; definition

2. Nature and stress injury concepts- theory
3. Causes of stress
4. Susceptibility to stress
5. Resistance to stress
6. Low temperature stress: freezing injury - related injuries
7. Resistance to low temperature in plants, measurement of freezing tolerance.
8. Chilling injury and resistance in plants,
9. Practical ways to overcome the effect of low temperature stress through, soil and crop

a. manipulations.

10. High temperature or heat stress: meaning & definition of heat stress,
11. Heat injury and resistance in plants,
12. Practical ways to overcome the effect of heat stress through soil and crop manipulations.
13. Water deficit stress: meaning of plant water deficient stress
14. Effect of water stress on growth and development,
15. Water deficit injury and resistance,
16. Practical ways to overcome effect of water deficit stress through soil and crop manipulations.
17. Excess water or flooding stress: meaning of excess water stress
18. Kinds of excess water stress and its effects on crop plants.
19. Excess water stress injury and resistance.
20. Practical ways to overcome excess water stress through soil and crop manipulations.
21. Salt stress – meaning of salt stress
22. Salt stress and its effect on crop growth,
23. Salt stress injury and resistance in plants,
24. Practical ways to overcome the effect of salt stress through soil and crop manipulations.
25. Mechanical impedance of soil and its impact on plant growth;
26. Measures to overcome soil mechanical impedance.
27. Environmental pollution – Definition and types of pollution
28. Air pollution and their effects on crop growth and quality of produce
29. Soil pollution and their effects on crop growth and quality of produce
30. Water pollution and their effects on crop growth and quality of produce
31. Ways and means to prevent environmental pollution.

PRACTICAL SCHEDULE

1. Determination of electrical conductivity of plant cell sap
2. Determination of osmotic potential and tissue water potential
3. Measurement of transpiration rate
4. Measurement of stomatal frequency
5. Measurement of Relative Water Content of leaf
6. Measurement of electrolytic leakage
7. Growing of plants in sand culture under salt stress for biochemical studies - I

8. Growing of plants in sand culture under salt stress for biochemical studies - II
9. Growing of plants in sand culture under salt stress for physiological studies - I
10. Growing of plants in sand culture under salt stress for physiological studies - II
11. Studies on effect of osmotic and ionic stress on seed germination and seedling growth
12. Measurement of low temperature injury under field conditions
13. Studies on plant responses to excess water.
14. Visit to industry/factory to assess the pollution
15. Visit to Coastal salinity/Dry farming Research station
16. Visit to Physiology /Tissue culture lab
17. **PRACTICAL EXAMINATION**

LEARNING OUTCOME

Experience on the knowledge of various types of stresses in crop production and strategies to overcome these.

SUGGESTED READING

Baker FWG.1989. *Drought Resistance in Cereals*. Oxon, UK.

Gupta US. (Ed.). 1988. *Physiological Aspects of Dryland Farming*. Oxford & IBH.

Kramer PJ.1983. *Water Relations of Plants*. Academic Press.

Levitt J. 1980. *Response of Plants to Environmental Stresses*. Vols. I, II. Academic Press.

Mavi HS.1978. *Introduction to Agro-meteorology*. Oxford & IBH.

Michael AM and Ojha TP.1981. *Principles of Agricultural Engineering*. Vol II. Jain Bros.

Nilsen ET and Orcut DM. 1996. *Physiology of Plants under Stress* – Abiotic Factors. John Wiley & Sons.

Singh K. 2000. *Plant Productivity under Environmental Stress*. Agribios Publ.

Singh KN and Singh RP. 1990. *Agronomic Research Towards Sustainable Agriculture*. Indian Society of Agronomy, New Delhi.

Somani LL and Totawat KL. 1992. *Management of Salt-affected Soils and Waters*. Agrotech Publ.

Virmani SM, Katyal JC, Eswaran H and Abrol IP. 1994. *Stressed Ecosystem and Sustainable Agriculture*. Oxford & IBH

Narayanan.AL.2021**.**Introductory Agrometeorology. Brillion Publishing, New Delhi

Narayanan.AL. 2015. *Principles of Applied Agricultural Meteorology*, Sri Velan Pathipagam, Chidambaram.

Journals

- Indian Journal of Agronomy
- Agronomy Journal
- Journal of Agrometeorology
- Mausam

Agron 608 Research and Publication ethics 2+0

AIM OF THE COURSE

To develop skill for research management and quality publication.

THEORY

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches. Ethics: definition, moral philosophy, nature of moral judgements and reactions. Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit II

Publication ethics: Definition, introduction and importance. Best practices/standard setting initiatives and guidelines: COPE, WAME, etc., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, Predatory publishers and journals

Unit III

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to check publisher copy right and self archiving policies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools viz., JANE, Elsevier Journal Finder, Springer Journal Suggester etc.

Unit IV

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open source software tools

Unit V

Database and Research metrics: Indexing data base, citation database, web of science, scopus, etc. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index altmetrics.

LECTURE SCHEDULE

1. Introduction to philosophy: definition, nature and scope,
2. Introduction to philosophy: concept, branches
3. Ethics: definition, moral philosophy, nature of moral judgements and reactions.
4. Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity
5. Scientific misconducts- falsifications, fabrications and plagiarism (FFP):
6. Redundant publications: duplicate and overlapping publications,
7. Salami slicing; selective reporting and misrepresentation of data
8. Publication ethics: Definition, introduction and importance

9. Best practices/standard setting initiatives and guidelines: COPE, WAME, etc., conflicts of interest
10. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa
11. Publication misconduct: types, violation of publication ethics, authorship and contributorship
12. Identification of publication misconduct, complaints and appeals
13. Predatory publishers and journals
14. Open access publishing: open access publication and initiatives
15. SHERPA, RoMEO online resource to check publisher copy right
16. Self archiving policies
17. Software tool to identify predatory publications developed by SPPU
18. Journal finder/journal suggestions tools viz., JANE, Elsevier Journal Finder, Springer Journal Suggester etc.
19. Publication misconduct: Group discussions
20. subject specific ethical issues
21. FFP
22. authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad.
23. Software tools: Use of plagiarism software like Turnitin, Urkund
24. Software tools: other open source software tools
25. Database and Research metrics:
26. Indexing data base
27. Citation database
28. Web of science, scopus, etc
29. Impact factor of journal as per journal citation report
30. SNIP, SJR, IPP, Cite Score
31. Metrics: h-index, g-index, i10-index altmetrics

LEARNING OUTCOME

Developed skill for research management, quality publication.

SUGGESTED READING

Kothari, C.R., 2004. *Research Methodology: Methods and Techniques*, New Age International Publ.

Hugo FjelstedAlroe and Erik Steen Kristensen, 2002. Towards a systemic research methodology in agriculture: Rethinking the role of values in science. *Agriculture and Human values*, **19**:3-23

Rana, S.S. and Suresh Kumar, 2014 *Research Techniques in Agronomy*, Department of Agronomy, College of Agriculture, CSK Himachal Pradesh KrishiVishvavidyalaya, Palampur, 64. P.

MINOR COURSE – TO BE OFFERED BY DEPT. OF AGRONOMY

AGM 601 Climate Change and Sustainable Development 2+1

AIM OF THE COURSE

To impart the theoretical and practical knowledge of climate change and the cause, effect, mitigation of climate change.

THEORY

Unit I

Climate change and global warming: definitions of terms; causes of climate change and global warming; greenhouse gases, ozone depletion; past records, present trends, extreme weather events and future projections; Case studies on various climatic projections and consequences thereof in relation to agriculture.

Unit II

Impacts of climate change on various systems: impacts resulting from projected changes on agriculture and food security; hydrology and water resources; terrestrial and freshwater ecosystems; coastal zones and marine ecosystems; human health; human settlements, energy, and industry; insurance and other financial services; climate change and crop diversification, loss of biodiversity, microbes and pest dynamics; climate change and storage, climate change and weed management. Advance methodology of assessing the impact of climate change on crops.

Unit III

Sensitivity, adaptation and vulnerability: system's sensitivity, adaptive capacity and vulnerability to climate change and extreme weather events; regional scenarios of climate change and variability.

Unit IV

Mitigation strategies for sustainable development: international policies, protocols, treaties for reduction in greenhouse gases and carbon emissions; carbon sequestration; carbon credit; Clean Development Mechanism (CDM) and land use, Crop management options for low emission, land use change and forestry mechanism, alternate energy sources, etc.

Unit V

Agricultural food security: reduction in carbon and GHG emission; fuel conservation and reduction in energy use, conservation tillage, biofuels for fossil fuels, reduction in machinery use etc; increasing carbon sinks; resource conservation technologies, mixed rotations of cover and green manure crops, minimization of summer fallow and no ground cover periods, etc.

PRACTICAL

- Case studies on various climatic projections and consequences thereof in relation to agriculture
- Advance methodology of assessing the impact of climate change on crops

LECTURE SCHEDULE

1. Climate change and global warming: definitions of terms
2. Causes of climate change and global warming
3. Greenhouse gases

4. Ozone depletion – past records and present trends,
5. Extreme weather events and future projections
6. Case studies on various climatic projections and consequences thereof in relation to agriculture.
7. Impacts resulting from projected changes on agriculture and food security
8. Impacts resulting from projected changes on hydrology and water resources
9. Impacts resulting from projected changes on terrestrial and freshwater ecosystems
10. Impacts resulting from projected changes on coastal zones and marine ecosystems
11. Impacts resulting from projected changes on human health and human settlements
12. Impacts resulting from projected changes on energy and industry
13. Impacts resulting from projected changes on insurance and other financial services;
14. Climate change and crop diversification, loss of biodiversity, microbes and pest dynamics;
15. Climate change and storage; climate change and weed management.
16. Advance methodology of assessing the impact of climate change on crops
17. Climate change and extreme weather events – system's sensitivity,
18. Climate change and extreme weather events – system's adaptive capacity
19. Climate change and extreme weather events – system's vulnerability;
20. Regional scenarios of climate change and variability.
21. Mitigation strategies for sustainable development:
22. International policies, protocols, treaties for reduction in greenhouse gases and carbon emissions
23. Carbon sequestration; carbon credit
24. Clean Development Mechanism (CDM) and land use
25. Crop management options for low emission – land use change and forestry mechanism, alternate energy sources, etc.
26. Agricultural food security – reduction in carbon and GHG emission
27. Agricultural food security – fuel conservation and reduction in energy use
28. Agricultural food security – conservation tillage, biofuels for fossil fuels, reduction in machinery use, etc.
29. Increasing carbon sinks – resource conservation technologies
30. Increasing carbon sinks – mixed rotations of cover and green manure crops
31. Increasing carbon sinks – minimization of summer fallow and no ground cover periods, etc.

PRACTICAL SCHEDULE

1. Institutions involved in climate change studies
2. Collection and analysis of observed trend and projection for different climate scenarios – World
3. Collection and analysis of observed trend and projection for different climate scenarios –India
4. Techniques for comparing station data with gridded historical runs
5. Identification of climatic hotspots – temperature (cold and heat waves)
6. Identification of climatic hotspots – rainfall (drought and flood)

7. Case studies on Climatic projections and consequences in relation to agriculture
8. Advanced methodology of assessing the impact of climate change on crops
9. Climate control experiments for identifying vulnerable crop stages.
10. Effect of elevated temperature on Crop production
11. Effect of elevated carbon di-oxide on Crop production
12. Incubation studies for GHGs assessment
13. Estimation of GHGs from field experiment
14. Estimation of GHGs from simulation model like DNDC
15. Remote sensing techniques for Climate change studies
16. Exposure visit to RMC, Chennai; IMD/DWRS, Karaikal; Climate Research centre, Anna University, Chennai.
17. **PRACTICAL EXAMINATION**

LEARNING OUTCOME

Will be aware on causes, impacts, mitigation and adaptations to climate change in the field of agriculture

SUGGESTED READING

Anonymous. Clean Development Mechanism: Building International Public-Private Partnership under Kyoto Protocol. UNEP, UNDP Publ.

Anonymous. IPCC Assessment Reports on Climate Change (2001, 2007). WMO, UNEP Publ.

Bishnoi OP. 2007. Principles of Agricultural Meteorology. Oxford Book Co.

Jepma CJ and Munasinghe M. 1998. Climate Change Policy: Facts, Issues and Analysis. Cambridge Univ. Press.

Mintzer IM. 1992. Confronting Climate Change: Risks, Implications and Responses. Cambridge Univ. Press.

Pretty J and Ball A. 2001. Agricultural Influence on Carbon Emission and Sequestration: A Review of Evidence and the Emerging Trading Options. Univ. of Essex.

Pretty JN. 1995. Regenerating Agriculture: Policies and Practices for Sustainable and Self Reliance. Earthscan.

Salinger J, Sivkumar MVK and Motha RP. 2005. Increasing Climate Variability of Agriculture and Forestry. Springer.

Sinha SK. 1998. Dictionary of Global Climate Change. Commonwealth

Journals

- Mitigation and Adaptation strategies for Global Change
- Climate Change
- Climate Risk Management
- Journal of Agrometeorology

Websites

- https://www.ipcc.ch/
- www.environment.gov.au/climate-change/climate-science-data/climate-science/ipc

Ph.D.
Genetics and Plant Breeding

Ph.D. Genetics and Plant Breeding

Sl No.	Course code	Course Title	Cr. Hr.
I.	**Major courses (12 credits)**		
01	GPB 601*	Advances in Plant Breeding systems	3+0
02	GPB 602	Advances in Biometrical Genetics	1+2
03	GPB 603	Molecular Cytogenetics for Crop Improvement	2+0
04	GPB 604	Plant Genetic Resources, Conservation and Utilization	2+0
05	GPB 605*	Genomics in Plant Breeding	3+0
06	GPB 606	Population Genetics	2+0
07	GPB 607	Crop Evolution	3+0
08	GPB 608	Breeding Designer Crops	1+1
09	GPB 609*	IPR and Regulatory Mechanism (e-course)	1+0
II.	**Minor Courses (6 credits)**		
01.	PGR 601	Recent advances in Germplasm Conservation	1+1
02.	PGR 602	Phenomics and Genomics for PGR Utilization	1+1
03.	PGR 607	*In-situ* on farm conservation	1+1
04.	MBB 602	Genome Engineering	3+0
05.	MBB 603	Omics and Molecular breeding	3+0
06.	MBB 604	Commercial Plant Tissue Culture	3+0
07.	SST 601	Hybrid Seed Production Technology	2+1
08.	SST 604	Genetic Purity and DUS Testing	2+1
09.	PP 602	Signal Perception and Transduction and Regulation of Physiological Processes	2+0
10.	PP 604	Plant Phenomics- Next generation Phenomics Platform	2+0
11.	PP 605	Experimental Techniques to Characterize Plant Processes for Crop Improvement	0+2
III.	**Supporting Courses (5 credits)**		
IV.	**Seminar (2 credits)**		
01	GPB 691	Doctoral Seminar	0+1
02	GPB 692	Doctoral Seminar	0+1
V.	**Thesis Research (75 credits)**		
01	GPB 699	Doctoral Research	0+75

* Courses to be compulsorily registered

GPB 601* ADVANCES IN PLANT BREEDING SYSTEMS 3+0

AIM OF THE COURSE

To impart theoretical knowledge about advances in plant breeding.

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. 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 II

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 III

Choice of molecular markers for plant breeding efficiency, fingerprinting and genetic diversity assessment, Gene pyramiding, accelerated backcrossing, marker-based utilization of exotic germplasm, introgression libraries. Genetic resources: primary, secondary, tertiary and alien trans gene pool; Molecular and biochemical basis of self-incompatibility and male sterility, nucleo-cytoplasmic interactions with special reference to male sterility – genetic, biochemical and molecular bases.

Unit IV

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;

Unit V

Apomixis and its use in heterosis breeding; Incongruity: Factors influencing incongruity Methods to overcome incongruity mechanisms. 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.

LECTURE SCHEDULE

1. Advances in reproductive biology of crops
2. Genes governing the whorls formation and various models proposed
3. Pollen pistil interaction: biochemical and molecular basis
4. Environmental factors governing anthesis and bottlenecks for gene transfer
5. Mating systems in Plant Breeding
6. Plant Breeding methodologies: Classic *versus* modern
7. Over view of Pre and Post-Mendelian breeding methods in self and cross pollinated crops
8. Molecular and transgenic breeding approaches
9. Doubled haploid breeding
10. Shuttle, forward and reverse breeding
11. Speed breeding and participatory plant breeding
12. Breeding for organic situations
13. Genetic basis of population improvement in crop plants
14. Principles and procedures in the formation of a complex population
15. Hybridization techniques for complex population formation
16. Recurrent selection methods in self and cross pollinated crops and their modifications
17. Recurrent selection- use in hybrid breeding programs
18. Reciprocal recurrent selection
19. Convergent selection and divergent selection
20. Selection in clonally propagated crops – Assumptions and realities
21. Choice of molecular markers for plant breeding efficiency
22. Fingerprinting and genetic diversity assessment
23. Application of MAS for selection of qualitative and quantitative traits
24. Marker based Gene pyramiding and accelerated backcrossing
25. **&** 26 Marker-based utilization of exotic germplasm, introgression libraries
27. Genetic resources: primary, secondary, tertiary and alien trans gene pool
28. Molecular and biochemical basis of self-incompatibility
29. Nucleo-cytoplasmic interactions with special reference to male sterility–genetic, biochemical and molecular bases
30. Genetic engineering technologies to create male sterility -part 1
31. Genetic engineering technologies to create male sterility -part 2
32. Prospects and problems of use of self- incompatibility and male sterility in plant breeding
33. Fertility restoration in male sterile lines and restorer diversification Programs
34. Conversion of agronomically ideal genotypes into male sterile lines
35. Stability of male sterile lines
36. Environmental influence on sterility
37. Environmentally Induced Genic Male Sterility (EGMS) – Types of EGMS; Influence on their expression, genetic studies
38. Photo and thermo sensitive genetic male sterility and its use in heterosis breeding
39. Temperature sensitive genetic male sterility and its use heterosis breeding
40. Apomixis and its use in heterosis breeding
41. Incongruity: Factors influencing incongruity Methods to overcome incongruity mechanisms

42. Breeding for climate change -Improving root systems
43. Breeding for abiotic stress tolerance, water use efficiency, flooding and sub-mergence Tolerance
44. Breeding for biotic stress tolerance
45. Breeding for high nutrient use efficiency, high nitrogen fixation and assimilation
46. Breeding for carbon farming-greenhouse gases and carbon sequestration
47. Breeding for bio-fortification in cereals
48. Breeding for bio-fortification in pulses and oilseed crops
49. Breeding for bio-fortification in fodder and fiber crops
50. Breeding for bio-fortification in vegetable crops
51. New Breeding Techniques (NBT)

LEARNING OUTCOME

Students 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.

SUGGESTED READINGS

1. Agarwal RL. 1996. Fundamentals of Plant Breeding and Hybrid Seed Production. Oxford & IBH.
2. Fehr WR. 1987. Principles of Cultivar Development: Theory and Technique. Vol I. Macmillan.
3. Kang MS and Priyadarshan PM (Edit.). 2007. Breeding Major Food Staples. Blackwell Publishing.
4. Kole C. 2013. Genomics and Breeding for Climate-Resilient Crops. Springer. Vol.II. Target Traits.
5. Mandal AK, Ganguli PK & Banerji SP. 1995. Advances in Plant Breeding. Vol. I, & II. CBS.
6. Richards AJ. 1986. Plant Breeding Systems. George Allen & Unwin.
7. Sharma JR. 1994. Principles and Practice of Plant Breeding. Tata McGraw-Hill.
8. Simmonds NW. 1979. Principles of Crop Improvement. Longman.
9. Singh BD. 1997. Plant Breeding-Principles and Methods. 5th Ed., Kalyani Publ.
10. Singh P. 1996. Essentials of Plant Breeding. Kalyani Publ.
11. Welsh JR. 1981. Fundamentals of Plant Genetic and Breeding. John Wiley.

SUGGESTED WEBSITE

1. https://www.researchgate.net/publication/281147777
2. https://www.frontiersin.org/articles/10.3389/fpls.2020.582011/full
3. https://onlinelibrary.wiley.com/doi/full/10.1002/aepp.13044

GPB 602. ADVANCES IN BIOMETRICAL GENETICS 1+2

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.

THEORY

Unit I

Continuous variation-evolutionary studies; Genetic principles of continuous variation, Qualitative and quantitative techniques-differences, population types, approaches; various types of metrices, 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 unweighted joint scaling test; Effect of linkage to generation mean, specification of mean to G x 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 x 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. 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/NAM populations, GWAS in crops.

Unit V

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. Genomic selection in crops.

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.

LECTURE SCHEDULE

1. Continuous variation-evolutionary studies. Genetic principles of continuous variation. Qualitative and quantitative techniques-differences, population types, and approaches
2. Various types of metrices, F_2, F_α and mixed-Selection of parents-Simultaneous selection models-Use of Multiple regression analysis in selection of genotypes
3. Components of mean-Additive effect, breeding value, coefficient of gene dispersion, Dominance
4. Simple scaling test, expectation of mean of character in various types of families in coupling and dispersed phase
5. Epistasis- Specification, weighted and unweighted joint scaling test-Effect of linkage to generation mean
6. Specification of mean to G x E interaction Component of variances-advantages, variances of different generations, balance sheet of variance
7. Estimation of parameters-weighted and unweighted Least square analysis. Random mating population; experimental population-BIPs

8.&9 NCD-I, II, III, Triple test cross for random mating population and inbreds

10. Estimates of linkage and non- allelic interactions-Combining ability analysis, Hayman's Approach, Graphical Approach
11. G x E Interaction, stability and adaptability Advanced models in stability analysis – Pattern analysis,
12. Additive Main Effect and Multiplicative Interaction (AMMI) analysis and other related models -Merits and limitation of different stability analysis methods
13. Analysis and selection of genotypes; Methods and steps to select the best model - Biplots and mapping genotypes
14. Construction of saturated linkage maps, concept of framework map development; QTLs different types of markers and mapping populations.
15. Linkage maps, mapping Strategies for QTL mapping-desired populations, statistical methods; MAGIC/NAM populations, GWAS in crops.
16. 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.
17. Linkage disequilibrium between markers and traits and selection methods; Use of advanced software packages for biometrical analysis, interpretation of analysed data. Genomic selection in crops

PRACTICAL SCHEDULE

1. Analysis of continuous variation – mean, variance, skewness and kurtosis-Use of

computer software for analysis of continuous variation

2. ABC scaling test and Joint scaling test- Analysis and interpretation
3. Generation mean analysis Estimation of variance of different filial generations and Interpretations
4. Generation mean analysis- 5 parameter
5. Generation mean analysis- 6 parameter
6. Use of computer packages for matting designs
7. Diallel analysis: Numerical
8. Diallel analysis- Graphical
9. Diallel analysis - partial diallel
10. Triallel analysis
11. L x T analysis
12. NC Designs
13. NC Designs
14. NC Designs
15. Triple test cross analysis
16 Use of computer packages for GxE interaction
17. Stability analysis: Eberhart model
18. Stability analysis: Russel model
19. Principal Component Analysis model
20. AMMI model
21. GGE Biplot
22. Shifted multiplicative model - Analysis and selection of genotypes
23. Methods and steps to select the best model
24. Biplots and mapping genotypes
25. Linkage analysis
26. QTL analysis
27. Construction of linkage maps and QTL mapping
28. Statistical methods in QTL mapping and GWAS.
29. Phenotype and Marker linkage studies-Use of advanced software in biometrical analysis
30. Use of computer packages for MAS
31. MAS-foreground and background selection
32. MAS-estimation of recurrent parent genome
33. Case studies of MAS, MABC and Genomic selection.
34. **Final practical examination**

LEARNING OUTCOME

Students 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.

SUGGESTED READINGS

1. Bos I & Caligari P. 1995. Selection Methods in Plant Breeding. Chapman & Hall.
2. DabholkarAR.1993. Elements of biometrical genetics. Concept Publishing Co. New Delhi.
3. Falconer DS and Mackay J. 1996. Introduction to quantitative genetics (4^{th} Ed.). ELBS/Longman, London.
4. Mather K & Jinks JL. 1985. Biometrical genetics (3rd Ed.). Chapman and Hall, London.

5. Nandarajan N. and Gunasekaran M. 2008. Quantitative Genetics and Biometrical Techniques in Plant Breeding. Kalyani Publ.
6. Roy D. 2000. Plant Breeding, Analysis and Exploitation of Variation. Narosa Publishing House, New Delhi.
7. Singh P & Narayanan SS. 1993. Biometrical Techniques in Plant Breeding. Kalyani Publ. Ludhiana.
8. Weir DS. 1990. Genetic Data Analysis. Methods for Discrete Population Genetic Data. Sinauer Associates.
9. Wricke G & Weber WE. 1986. Quantitative Genetics and Selection in Plant Breeding. Walter de Gruyter.

SUGGESTED WEBSITE

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

GPB 603 MOLECULAR CYTOGENETICS FOR CROP IMPROVEMENT 2+0

AIM OF THE COURSE

To expose the students on applications of molecular cytogenetic techniques for crop improvement.

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. Application of Flow cytometry in cytogenetics.

Unit II

Karyotyping–Chromosome banding and chromosome painting. Tracking introgressions using FISH, GISH, localisation and mapping of genes/genomic segments. Pre-breeding and applications of cytogenetical methods for crop improvement; Location and mapping of genes on chromosomes: deficiency method.

Unit III

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; MAAL, DAAL & CSSL in wide hybridization. Intervarietal substitutions-allelic and non-allelic interactions. Telocentric method of mapping. Cytogenomics-Concept, tools and techniques for crop improvement;

Unit V

Chromosome sorting: Isolation of specific chromosome for development of molecular maps and gene location. 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.

LECTURE SCHEDULE

1. Organization and structure of genome, Genome size
2. Organization of organellar genomes, Nuclear DNA organization
3. Nuclear and Cytoplasmic genome interactions and signal transduction
4. Inheritance and expression of organellar DNA
5. Variation in DNA content-C value paradox
6. Sequence complexity–Introns and Exons, Repetitive sequences, Role of repetitive Sequence
7. Karyotyping–Chromosome banding and chromosome painting

8. Tracking introgressions using FISH and GISH
9. Localization and mapping of genes/genomic segments
10. Pre-breeding and applications of cytogenetical methods for crop improvement
11. Location and mapping of genes on chromosomes: deficiency method; Interchange genetic consequence, identification of chromosomes involved and gene location
12. Balanced lethal systems, their maintenance and utility
13. Multiple interchanges-use in producing inbreds, transfer of genes-linked marker methods
14. Duplication - production and use
15. Inversions and location of genes
16. B/A chromosome translocations and gene location
17.&18. Trisomics-types, production, breeding behavior and location of genes
19. Use of balanced tertiary trisomics in hybrid seed production
20. Monosomics methods of production, breeding behavior and location of genes
21. Intervarietal substitutions-allelic and non-allelic interactions
22. Telocentric method of mapping
23. Cytogenomics: Concept, tools and techniques for crop improvement
24. MAAL, DAAL, CSSL and MASL
25. Gene identification using aneuploidy
26. Chromosome sorting: Isolation of specific chromosome for development of molecular maps and gene location
27. Role of polyploidy in crop evolution and breeding
28. Autopolyploids in crop evolution and breeding
29. Allopolyploids in crop evolution and breeding
30. Distant hybridization
31. Barriers to interspecific hybridization
32. Barriers to intergeneric hybridization
33. Behaviour of interspecific crosses
34. Behaviour of intergeneric crosses

LEARNING OUTCOME

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

SUGGESTED READINGS

1. Clark MS & Wall WJ. 1996. Chromosomes: The Complex Code. Chapman & Hall.
2. Conger BV.(Ed.). 1981. Cloning Agricultural Plants *via in vitro* Techniques. CRC Press. 31 January 2018.
3. Constabel F & Vasil IK. 1988. Cell Culture and Somatic Cell Genetics of Plants. Vol. V. Cell Culture and Phytochemicals in Plant Cell Cultures. Academic Press.
4. Gupta P K .2006. Cytogenetics. Rastogi Publisher.
5. Lal R & Lal S. 1990. Crop Improvement Utilizing Biotechnology. CRC Press.
6. Mantel SH & Smith H. 1983. Plant Biotechnology. Cambridge University Press.
7. Yao-Shan F. 2002. Molecular Cytogenetics: Protocols and Application. Human Press.

SUGGESTED WEBSITES

1. https://www.researchgate.net/publication/238752513_
2. https://academic.oup.com/bfg/article/9/2/95/216151

GPB 604 PLANT GENETICS RESOURCES, CONSERVATION AND UTILIZATION 2+0

AIM OF THE COURSE

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

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 cryoprotectants, 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.

LECTURE SCHEDULE

1. Concept of natural reserves and natural gene banks
2. *In situ* conservation of wild species in nature reserves
3. *In situ* conservation components, factors influencing conservation value
4. National plan for in situ conservation
5. *In situ* conservation of agro biodiversity on-farm measures
6. Scientific basis of in situ conservation on-farm, building on farm conservation initiatives implementation of on-farm conservation
7. Management of in situ conserved genetic diversity on-farm

8. Enhancing benefits for farmers from local crop diversity
9. *Ex situ* conservation: components, plant genetic resources conservation in gene banks
10. National gene banks, gene repositories
11. Preservation of genetic materials under natural conditions
12. Perma-frost conservation of Crop plants
13. Guidelines for seed multiplication and exchange to network of active/working collections, orthodox, recalcitrant seeds differences in handling
14. Clonal repositories
15. Genetic stability under long term storage condition
16. In vitro storage, maintenance of in vitro culture under different conditions
17.&18. *In vitro* bank maintenance for temperate and tropical fruit crop species
19. *In vitro* bank maintenance for spices, tubers
20. *In vitro* bank maintenance for bulbous crops, medicinal and endangered plant species
21. Conservation of embryos and ovules, cell/suspension cultures, protoplast and callus cultures
22. Conservation of pollen culture
23. Micropropagation techniques, problems, prospects of *in vitro* gene bank
24. Cryopreservation- procedure for handling seeds of orthodox and recalcitrant seeds
25. Cryoprotectants, desiccation, rapid and slow freezing, vitrification and dehydration techniques
26. National facilities, achievements in Cryopreservation
27. Application of cryopreservation in agricultural crops
28. Application of cryopreservation in horticultural and forestry crops
29. Problems and prospects in Cryopreservation and challenges ahead
30. Concept and procedure for PGR management
31. Germplasm characterization and evaluation
32. Concept of core and mini core collections
33. Germplasm utilization in field crops-Case studies
34. Registration of plant germplasm at National Level

LEARNING OUTCOME

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

SUGGESTED READINGS

1. Ellis RH, Roberts EH & 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.
2. Frankel OH & Hawkes JG.1975. Crop Genetic Resources for Today and Tomorrow. Cambridge University Press, Cambridge.
3. Paroda RS and Arora RK.1991. Plant Genetic resource Conservation and management, NBPGR, New-Delhi.
4. Simmonds NW. 1979. Principles of Crop Improvement. Longman.
5. Westwood MN. 1986. Operation Manual for National Clonal Germplasm Repository Processed Report. USDA-ARS and Oregon State Univ. Oregon, USA.
6. Withers LA. 1980. Tissue Culture Storage for Genetic Conservation. IBPGR Tech. Rep. IBPGR, Rome, Italy.

SUGGESTED WEBSITES

1. https://cropgenebank.sgrp.cgiar.org/index.php/procedures-mainmenu-242/ characterization -mainmenu-205
2. https://www.frontiersin.org/articles/10.3389/fpls.2014.00068/full
3. https://www.iaea.org/sites/default/files/21/06/nafa
4. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7907825/
5. https://www.pnas.org/content/96/11/5937
6. https://academic.oup.com/bfg/article/17/3/198/4982565

GPB 605* GENOMICS IN PLANT BREEDING 3+0

AIM OF THE COURSE

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

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. Genome sequencing: Principles and techniques of conventional approaches and next generation sequencing including sequencing-by-synthesis/ligation and single molecule real time (SMRT) technologies

Unit II

Applications of sequence information: structural, functional and comparative genomics; Plant genome projects: Strategies for genome sequencing including shot gun and clone-by-clone method. 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

Unit III

Integration of genetic and physical map for map-based cloning of economically important genes. Concept of allele mining; Diversity array technology: concepts and applications. Functional genomics: concept of reverse and forward genetics; Use of activation tagging, transposon tagging, insertional mutagenesis, TILLING and ecoTILLING for crop improvement.

Unit IV

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. 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 V

Recent transgene free genome editing tools such as CRISPR-Cas9 system, TALENS and ZFNs for crop improvement. Cis-genesis and Intra-genesis 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).

LECTURE SCHEDULE

1. Introduction to the plant genome
2. Nuclear, chloroplast and mitochondrial genomes
3. Genome size and complexity, C value paradox

4. Types of DNA sequences, repetitive and unique DNA sequences
5. Genome sequencing: Principles and techniques of conventional approaches
6. Generations of sequencing technology, next generation sequencing technologies
7. Application of sequence information in structural, functional and comparative genomics
8. Plant genome projects – completed and ongoing projects
9. Strategies for genome sequencing – shot gun and clone by clone method
10. Molecular markers – types
11. Uses of molecular markers in genetic and physical mapping
12. Molecular mapping of major gene
13. Molecular mapping of QTLs
14. Linkage and LD based gene mapping
15. Genome wide association studies (GWAS) and association analysis
16. GWAS – case studies
17. Map based cloning of important genes
18. Map based cloning of genes - Case studies
19. Concepts of allele mining
20. Diversity array technology – concepts and application
21. Diversity array – case studies
22. Functional genomics: Concept of reverse and forward genetics
23. Uses of activation tagging, transposon tagging, insertional mutagenesis
24. TILLING and Eco TILLING

25.&26.TILLING and Eco TILLING – case study

27. Gene specific transcriptomics approaches: Serial analysis of gene expression
28. Microarray
29. Microarray – case study
30. Northern hybridization
31. RT PCR and QRT PCR – uses
32. Plant genome data base
33. Bioinformatic tools
34. Application of bioinformatics tools in genomics
35. Concept and application of high throughput proteomics
36. Concept and application of high throughput metabolomics
37. Concept and application of high throughput phenomics
38. Concepts of genome editing in plants
39. CRISPR – Cas 9 system – principle and methods
40. CRISPR – Cas 9 system – case study
41. TALENS and ZENs for improvement
42. Cis-genesis and intra-genesis tools as twin sisters for crop improvement
43. Genome wide genetic diversity studies
44. Identification of molecular makers linked to major gene and QTLs
45. Marker validation and conversion of markers suitable for MAS
46. Marker assisted selection – methods, merits
47. Marker assisted selection – case study
48. Marker assisted backcrossing
49. Marker assisted backcrossing – case study
50. Association mapping
51. Breeding by design and Genomic selection

LEARNING OUTCOME

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.

SUGGESTED READINGS

1. Alonso JM, Stepanova AN. (2015). Plant Functional Genomics: Methods and Protocols. Springer.
2. Chopra VL, Sharma RP, Bhat SR and Prasanna BM. (2007) Search for New Genes. Academic Foundation, New Delhi.
3. Hackett PB, Fuchs JA & Messing JW. 1988. An Introduction to Recombinant DNA Technology - Basic Experiments in Gene and Manipulation. 2nd Ed. Benjamin Publ. Co.
4. Primose SB & Twyman RM. 2006. Principles of Gene Manipulation and Genomics. 7th Ed. Wiley-Blackwell Publishing.

SUGGESTED WEBSITES

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

GPB 606 POPULATION GENETICS 2+0

AIM OF THE COURSE

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

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, Non-random mating: selfing – inbreeding coefficient, panmictic index, sib-mating, Assortative mating and disassortative mating; Pedigree populations and close inbreeding, Estimation of linkage disequilibrium, Correlation between relatives and estimation of F value. Effect of inbreeding and sibbing in cross pollinated crops.

Unit V

` Gene substitution and average effects; Breeding value- Genetic drift; Genetic slippage, Co-adapted gene complexes; Homoeostasis- Adaptive organization of gene pools; Polymorphism- Balanced and Non-balanced polymorphism, heterozygous advantage- Survival of recessive and deleterious alleles in populations.

LECTURE SCHEDULE

1. Population: Properties of population, Mendelian population
2. Genetic constitution of a population through time, space, age structure etc
3. Frequencies of genes and genotypes
4. Causes of change: population size, differences in fertility and viability
5. Causes of change: migration and mutation
6. Hardy-Weinberg equilibrium, Hardy-Weinberg law
7. Proof and applications of the Hardy-Weinberg law
8. Test of Hardy-Weinberg equilibrium
9. Mating frequencies: Non-dominance

10. Mating frequencies: Co-dominance
11. Snyder's ratio
12. Mating frequencies - importance and its effect over random mating in succeeding generations
13. Multiple alleles
14. Sex linked genes
15. Use of gene and genotypic frequencies evaluation in field population level
16. Interpretations - Changes of gene frequency- Migration, Mutation

17.&18. Interpretations - Changes of gene frequency- Recurrent and non-recurrent Selection

19. Balance between selection and mutation
20. Selection favoring heterozygotes
21. Over dominance for fitness
22. Mating systems, Random mating population
23. Non-random mating: selfing –inbreeding coefficient, panmictic index , sibmating
24. Non-random mating: Assortative mating and disassortative mating;
25. Pedigree populations and close inbreeding
26. Estimation of linkage disequilibrium
27. Correlation between relatives and estimation of F value.
28. Effect of inbreeding and sibbing in cross pollinated crops
29. Gene substitution and average effects
30. Breeding value- Genetic drift
31. Genetic slippage, Co-adapted gene complexes
32. Homoeostasis- Adaptive organization of gene pools
33. Polymorphism- Balanced and Non-balanced polymorphism
34. Heterozygous advantage- Survival of recessive and deleterious alleles in populations

LEARNING OUTCOME-

The student will be well versed with population genetics, its components and applications in crop improvement.

SUGGESTED READINGS

1. Chawla V & Yadava RK. 2006. Principles of Population Genetics – A Practical Manual. Dept. of Genetics, CCS HAU, Hisar.
2. Falconer DS & Mackay J.1996. Introduction to Quantitative Genetics. Longman.
3. Jain JP, Jain J &Parbhakaran VT. 1992. Genetics of Populations. South Asia Books.
4. Li CC. 1955. Population Genetics. The Univ. of Chicago Press.
5. Mather K & Jinks JL. 1982. Biometrical Genetics. Chapman & Hall.
6. Sorrens D &Doniel G. 2007. Methods in Quantitative Genetics. Series: Statistics for Biology and Health. Likelihood.
7. Tomar SS. 1992. Text Book of Population Genetics. Universal Publication.

SUGGESTED WEBSITES

1. http://darwin.eeb.uconn.edu/eeb348/lecturenotes/notes.html
2. http://dorakmt.tripod.com/evolution/popgen.html
3. http://nitro.biosci.arizona.edu/courses/EEB182/Lecture04/lect4.html

GPB 607 CROP EVOLUTION (3+0)

AIM OF THE COURSE

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

THEORY

Unit I

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

Unit II

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

Unit III

Processes in crop evolution and stabilization of polyploids, cytogenetic and genetic stabilization; Genome organization – Transgenesis in crop evolution, Multifactorial genome, Intragenomic interaction, Intergenomic interaction, Genome introgression;

Unit IV

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 V

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.

LECTURE SCHEDULE

1. Origin and evolution of species
2. Centers of diversity/origin
3. Diffused centres
4. Time and place of domestication
5. Patterns of evolution and domestication-examples and Case studies
6. Patterns of evolution and domestication-examples and Case studies
7. Patterns of evolution and domestication-examples and Case studies
8. Patterns of evolution and domestication-examples and Case studies
9. Domestication and uniformity
10. Characteristics of early domestication and changes
11. Concept of gene pools and crop evolution

12. Selection and Genetic drift - Consequences
13. Speciation and domestication
14. Process of speciation
15. Reproductive isolation barriers
16. Genetic differentiation during speciation
17. Hybridization - speciation and extinction
18. Exploitation of natural variation
19. Early attempts to increase variation
20. Distant hybridization and introgression
21. Inter-specific hybridization-scope and limitations, techniques to overcome the limitations
22. Inter-generic hybridization-scope and limitations, techniques to overcome the limitations
23. Gene transfer into cultivated species, tools and techniques
24. Validation of transferred genes and their expression
25. &26. Controlled introgressions
27. Processes in crop evolution and stabilization of polyploids-Autopolyploids
28. Processes in crop evolution and stabilization of polyploids-Allopolyploids
29. Cytogenetic and genetic stabilization
30. Genome organization –Transgenesis in crop evolution
31. Multifactorial genome
32. Intragenomic interaction
33. Intergenomic interaction
34. Genome introgression
35. Methods to study crop evolution-Contemporary methods, based on morphological features, Cytogenetic analysis, Allozyme variations and crop evolution, DNA markers, genome analysis and comparative genomic
36. 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
37. Allozyme variations and crop evolution
38. Methods to study crop evolution - DNA markers, genome analysis and comparative genomics
39. Evolutionary significance of polyploidy
40. Evolution of crop plants through ploidy manipulations
41. Polyploids: methods, use of autopolyploids
42. Polyploids: methods, use of haploidy
43. DH-method of production and use
44. Polyploids: methods, use of allopolyploids
45. Synthesis of new crops
46. Case studies – Cereals
47. Case studies – Pulses
48. Case studies – Oilseeds
49. Case studies – Fibre crops and Forage crops
50. Case studies – Vegetables and Plantation crops
51. Case studies – Tuber crops and Medicinal Plants

LEARNING OUTCOME

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.

SUGGESTED READINGS

1. Hancock JF. 2004. Plant Evolution and the Origin of Crop Species. 2nd Ed. CABI.
2. Ladizinsky G. 1999. Evolution and Domestication. Springer.
3. Miller AJ. 2007. Crop Plants: Evolution. John Wiley & Sons.
4. Smartt J & Simmonds NW. 1995. Evolution of Crop Plants. Blackwell

SUGGESTED WEBSITES

1. https://genomebiology.biomedcentral.com/articles/10.1186/s13059-018-1528-8
2. https://pubmed.ncbi.nlm.nih.gov/17933510/
3. https://www.cell.com/trends/plant-science/fulltext/S1360-1385(21)00032-7

GPB 608 BREEDING DESIGNER CROPS (1+1)

AIM OF THE COURSE

Breeding crops for higher physiological efficiency and nutritional enhancement.

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.

PRACTICALS

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.

LECTURE SCHEDULE

1. Crop ideotype: History and Achievements
2. Breeding of crop ideotypes
3. Genetic manipulations through recombination breeding, genomics and transgenics for physiological efficiency and nutritional enhancement
4. Genetic manipulations through recombination breeding, genomics and transgenics for special compounds-proteins, vaccines, gums, starch and fats
5. Physiological efficiency of a crop plants as a concept, parametric and whole plant physiology in integrated mode

6. Physiological mechanisms of improvement in nutrient use efficiency, water use efficiency, osmotic adjustment, and its significance in crop improvement
7. Physiological mechanism of improvement in photosynthetic efficiency, stay green trait and its significance in crop improvement
8. &9. Breeding for special traits and determination of genetics of traits viz., oil, protein, vitamins, amino acids etc.
10. Ecospecific ideotypes - Ideotypes for high and low moisture conditions, low and high input conditions,
11. Conversion mechanism of C_3 to C_4 plants
12. Improvement in yield potential under sub-optimal conditions by manipulating source and sink, canopy architecture, plant-water relationships
13. Effect of suboptimal conditions on cardinal plant growth and development processes, enhancing input use efficiency through genetic manipulations
14. Concept of biopharming and development of varieties producing targeted compounds, nutraceuticals and industrial products
15. Success stories in vaccines, modified sugars, gums and starch through biopharming.
16. Biosafety management, segregation and isolation requirements in designer crop production
17. Biosafety management, segregation and isolation requirements Post-harvest management

PRACTICAL SCHEDULE

1. Measurement of Relative water content in plant tissues
2. Experiments in Water use efficiency in crop plants
3. Determination of osmotic pressure potential of living cells
4. Experiments in transpiration efficiency
5. Assess the phenomenon of transpiration through stomata
6. Measurement of respiration
7. Screening techniques under stress conditions such as electrolyte leakage, TTC
8. Measurement of absorption spectrum of chlorophyll
9. Experiments in chlorophyll fluorescence
10. Canopy temperature depression assessment
11. Measurement of stomatal density, stomatal index & perimeter of stomata in different leaves
12. Assessing continuity of intercellular spaces of a leaf and their relation to stomata
13. Evaluation of stomatal conductance
14. Study on mechanism of opening and closing of stomata
15. Estimation of chlorophyll content in plant tissues
16. Assessment of heat/drought/salt shock proteins
17. **Final practical examination**

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.

SUGGESTED READINGS

1. Balint A. 1984. Physiological Genetics of Agricultural Crops.
2. AK Ademiaikiado. Hay RK. 2006. Physiology of Crop Yield. 2nd Ed. Blackwell.
3. Pessarakli M. 1995. Handbook of Plant and Crop Physiology.

4. Marcel Dekker. Taiz L and Zeiger E. 2006. Plant Physiology. 4th Ed. Sinauer Associates.

SUGGESTED WEBSITES

1. https://www.ncbi.nlm.nih.gov/pmc/articles
2. https://www.researchgate.net/publication/271509580
3. https://www.cell.com/trends/plant-science/fulltext/S1360-1385(21)00069-8
4. https://www.frontiersin.org/articles/10.3389/fpls.2016.00539/full

GPB 609* IPR AND REGULATORY MECHANISM (E-COURSE) (1+0)

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.

THEORY

Unit I

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.

Unit II

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.

Unit III

Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection.

Unit IV

National Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture.

Unit V

Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

LECTURE SCHEDULE

1. Historical perspectives and need for the introduction of Intellectual Property Right regime
2. TRIPs and various provisions in TRIPS Agreement
3. Intellectual Property and Intellectual Property Rights (IPR)
4. Benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties
5. Fundamentals of patents
6. Copyrights, geographical indications
7. Designs and layout, trade secrets and traditional knowledge, trademarks

8. &9. Protection of plant varieties and farmers' rights

10. Biodiversity protection
11. Protectable subject matters, protection in biotechnology
12. Protection of other biological materials
13. Ownership and period of protection
14. National Biodiversity protection initiatives; Convention on Biological Diversity
15. International Treaty on Plant Genetic Resources for Food and Agriculture
16. Licensing of technologies
17. Material transfer agreements, Research collaboration Agreement, License Agreement

LEARNING OUTCOME

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.

SUGGESTED READINGS

1. Erbisch FH &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 & Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. State of Indian Farmer. Vol. V. Technology Generation and IPR Issues. Academic Foundation.

SUGGESTED WEBSITES

1. https://www.wto.org/english/tratop_e/trips_e/intel1_e.htm
2. https://www.cbic.gov.in/htdocs-cbec/ipr-notfns
3. https://ipindia.gov.in

PGR 601 RECENT ADVANCES IN GERMPLASM CONSERVATION 1+1

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.

THEORY

Unit I

Seed development and maturation; Seed storage behaviour: 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 seed gene 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,

UNIT IV

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,

UNIT V

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.

PRACTICAL

Seed morphology and structure. Desiccation rates and freezing to low and ultra low temperatures, seed storage behaviour determination in sample seeds, seed viability and vigour tests; Seed longevity and accelerated ageing test in different types of seeds, handling hard seededness and physiological immaturity; Post harvest handling methods of difficult-to-store seeds, dormant buds, and pollen, ultra-desiccation of seeds, biochemical tests of seed deterioration; Preparation of stock solutions, culture media, cryoprotectant solutions and regrowth media, Isolation of explants and *in vitro* culturing in growth retarding media for slow growth conservation, meristem isolation in dicots and monocots; Pretreatments, preculturing, cryoprotectant treatments varying temperature and durations, cold hardening-

plants and explants, cryopreservation techniques- encapsulation-dehydration, vitrification, encapsulation-vitrificaion, droplet freezing, thawing- slow and fast, recovery and regrowth-media, light conditions; *In* vitro-cryo-gene banking and database management, morphological and molecular markers for assessing genetic stability-demonstration.

LECTURE SCHEDULE

1. Seed development and maturation
2. Seed storage behaviour: physiological and molecular basis of desiccation sensitivity
3. Dormancy, seed germination- mobilization of reserves and their control processes
4. Viability and vigour-principle and testing procedures; Seed testing for inadvertent introduction of transgenes.
5. Seed storage for long-term conservation and factors affecting seed longevity.
6. seed processing for short, medium and long-term storage, artificial aging and controlled deterioration test
7. Ultra-desiccation techniques for germplasm conservation**,** richness index, ecological correlates of *ex-situ* seed longevity; Permafrost conservation, maintenance of Seed Genebank, status of global seed gene banks.
8. *In-vitro* techniques in PGR management, *In-vitro* methods of clonal propagation, *In-vitro* collecting and germplasm exchange,
9. 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* gene bank,
10. Status of World cryo- and cryo-gene banks, embryo rescue technique,
11. History and principles of cryopreservation, cryoprotectants- role and applicability, freezing injury and factors affecting cryoprotection,
12. Methods of cryopreservation conventional and vitrification based techniques,
13. Varied applications of cryopreservation, handling difficult-to store non-orthodox seeds, embryonic axes, pollen and dormant buds,
14. Management of *in-vitro*, cryo and DNA gene bank- Practical considerations,
15. Monitoring genetic stability of *in-vitro* conserved and cryopreserved germplasm,
16. Database management for *in-vitro* and cryopreserved germplasm.

PRACTICAL SCHEDULE

1. Seed morphology and structure;
2. Desiccation rates and freezing to low and ultra-low temperatures,
3. Seed storage behaviour determination in sample seeds,
4. Seed viability and vigour tests
5. Seed longevity and accelerated ageing test in different types of seeds, handling hard seededness and physiological immaturity
6. Post-harvest handling methods of difficult-to-store seeds, dormant buds, and pollen,
7. Ultra-desiccation of seeds, biochemical tests of seed deterioration
8. Preparation of stock solutions, culture media, cryoprotectant solutions and regrowth media,
9. Isolation of explants and *in vitro* culturing in growth retarding media for slow growth conservation,
10. Meristem isolation in dicots and monocots;
11. Pretreatments, preculturing, cryoprotectant treatments varying temperature and durations
12. Cold hardening protocol- plants and explants
13. Cryopreservation techniques. Encapsulation, dehydration vitrification, droplet

freezing

14. Cryopreservation techniques -thawing- slow and fast, recovery and regrowth- media, light conditions.
15. *In* vitro-cryo-genebanking and database management
16. Morphological and molecular markers for assessing genetic stability-demonstration.
17. **Final Practical Examination**

LEARNING OUTCOME

Advanced conservation techniques including biotechnological tools would be learnt by students.

SUGGESTED READING

1. Barbara MR, Chin HF and Normah MN. 2013. Conservation of Tropical Plant Species. Springer.
2. Bewley JD and Black M. 1994. *Seeds Physiology of Development and Germination,* Second Edition. Plenum Press, New York and London.
3. Chaudhury R and Malik SK. 2017. *Cryopreservation of Plant Species: Practical Approaches from Handling to Cryobanking.* ICAR-NBPGR, New Delhi. 52 p.
4. 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.
5. Cromarty A. 1984. Techniques of drying seeds, pp. 88-125. *Seed Management Techniques for Genebank* (JB Dicke, S Linington and J T Williams, eds). International Board on Plant Genetic Resources, Rome.
6. 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.
7. 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.
8. 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.
9. Ellis RH. 1988. The viability equation, seed viability monographs, and practical advice on seed storage. *Seed Science and Technology* 16: 29-50.
10. Hong TD and Ellis RH. 1996. A protocol to determine seed storage behaviour. International Plant Genetic Resources Institute IPGRI Technical Bulletin No. 1, Rome.
11. 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.
12. Reed BM. 2008. Cryopreservation—Practical Considerations. In: Reed B.M. (eds.) Plant Cryopreservation: A Practical Guide. Springer, New York, NY

13 Roberts EH. 1972. *Viability of Seeds.* Chapman and Hall, London.

PGR 602 PHENOMICS AND GENOMICS FOR PGR UTILIZATION (1+1)

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.

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;

Unit III

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 IV

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,

Unit V

Identification of desirable genes and alleles, germplasm characterization, trait mapping, genome sequencing, High throughput genotyping - GBS, association mapping studies: GWAS, molecular tagging of QTLs, FIGS.

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.

LECTURE SCHEDULE

1. Advances in phenotyping to overcome limitations in use of germplasm collections
2. Advanced methodology of germplasm evaluation and predictive methods for identification of useful germplasm
3. Phenomics facility, quantitative imaging techniques using remote sensing.
4. Experimental designs, analyses of evaluation data and database management.
5. Evaluation of crop germplasm for agronomic traits

6. Evaluation against biotic/ abiotic stresses; Evaluation against quality attributes and other value addition traits.
7. Management and utilization of crop germplasm, germplasm registration, Core and minicore collections

8.&9. Germplasm enhancement/ pre-breeding and use of wild relatives in crop improvement,

10. Embryo rescue method, pollen physiology and storage,
11. Integration of big data into breeding programs,
12. Harmonising agro-biodiversity conservation and agricultural development. New crops of the future, biofortified crops.
13. Uses and applications of molecular markers in PGR
14. Analysis of genetic diversity, identification of gaps in collection, molecular cytology,
15. Establishment of core and mini-core collections using molecular markers,
16. Identification of desirable genes and alleles, germplasm characterization,
17. Trait mapping, genome sequencing, High throughput genotyping-GBS, Association mapping studies GWAS, molecular tagging of QTLs, FIGS.

PRACTICAL SCHEDULE

1. Management and utilization of crop germplasm
2. Exercise for developing core set, mini core collection
3. High throughput phenotyping techniques
4. Usage of drones in PGR
5. Validation using molecular markers
6. Evaluation of crop germplasm for agronomical traits
7. Evaluation of crop germplasm for value addition
8. Evaluation of crop germplasm against biotic stress
9. Evaluation of crop germplasm against abiotic stresses;
10. Evaluation of germplasm for quality traits;
11. Biochemical characterization of germplasm.
12. Physiological characterization of germplasm.
13. Molecular characterization of germplasm
14. High throughput genotyping – GBS
15. Association mapping studies GWAS
16. Molecular tagging of QTLs, FIGS
17. **Final Practical Examination**

LEARNING OUTCOME

Students would be exposed to latest methodologies for characterizing the germplasm for maximum utilization

SUGGESTED READING

1. Brown AHD, Clegg MT, Kahler AL and Weir BS (eds.). 1990. *Plant population genetics, breeding, and genetic resources*, Sinauer Associates, USA.
2. Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The use of plant genetic resources.* Cambridge University Press.
3. Frankel OH and Hawks JG. 1975. *Crop genetic resources for today and tomorrow.* Cambridge University Press.
4. Frankel OH and Michaele ES. 1987. *Conservation and evolution.* Cambridge University Press.
5. Frankel R and Galun E. 1977. *Pollination mechanisms, reproduction and plant breeding.*

6. Genetic Data Analysis II: methods for Discrete Population Genetic Data. Sinauer Associates, Massachusetts, USA.
7. Griffin HG and Griffin AM. 1994. *PCR Technology: Current Innovations.* CRC Press, London.
8. Harlan JR. 1992. *Crops and Man* (Second Edition). American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA.
9. Hayward MD, Bosemak NO and Romagosa I. 1993. *Plant Breeding: Principles and Practices.* Chapman & Hall.
10. Holden JHN and Williams JT. 1984. *Crop genetic resources: conservation and evaluation,* IBPGR.
11. Hillis, D and Moritz C. 1990. Molecular Systematics. Sinauer Associates, USA.
IPGRI. 1997. Regeneration of accessions in seed collections: a decision guide: Handbook for gene banks No. 5.
12. Karp A, Isaac PG and Ingram DS. 1998. *Molecular Tools for Screening Biodiversity - Plants and Animals.* Chapman and Hall, London.
13. Lynch M and Walsh B. 1998. *Genetics and analysis of quantitative traits.* Sinauer Associates, Massachusetts, USA.
14. Peterson WW, Marie-Noelle N and Robert JH. 2018. Role of genomics in promoting the Utilization of plant genetic resources in gene banks. *Briefings in Functional Genomics* 17(3): 198- 206.
15. Stoskopf NC. 1993. *Plant Breeding: Theory and practice.* Westview Press.
16. TanksleySD and Orton TJ. 1983. *Isozymes in Plant Genetics and Breeding,* Part A and B. Elsevier Science Publication, Amsterdam.
17. 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.

PGR 607 *IN SITU* ON-FARM CONSERVATION (1+1)

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.

THEORY

Unit I

Biological diversity in India - importance - need for conservation- 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, Phyto-geographic surveys and inventory, estimation of genetic diversity, population biology, concept of minimum viable population, population viability and population genetics theory.

Unit II

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 agro-biodiversity, Delhi Declaration on Agrobiodiversity.

Unit III

Social, cultural and economic factors influencing crop genetic diversity, Agro-ecosystem factors: natural and farmer-managed, agro-morphological 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.

Unit V

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.

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.

LECTURE SCHEDULE

1. Biological diversity in India and its importance, germplasm conservation, concept of natural reserves and gene banks.
2. Types of germplasm conservation, factors influencing conservation; *in-situ* conservation components - biosphere reserve and natural parks, national programmes and on farm conservation.

3. Ex-situ conservation and its components.
4. *In situ* conservation of wild species in nature reserves, *In situ* conservation of crop diversity on-farm.
5. Phytogeographic surveys and inventory, estimation of genetic diversity, population biology, concept of minimum viable population, population viability and population genetics theory.
6. Designation of gene management zones (GMZs)/ gene sanctuaries, management and monitoring of GMZs.
7. Threat of genetic erosion, conservation agency priorities, biologically important species,
8. National action plan for agro-biodiversity, Delhi Declaration on Agro-biodiversity. Social, cultural and economic factors influencing crop genetic diversity.

9.&10. Social, cultural and economic factors influencing- Agro-ecosystem factors: natural and farmer-managed, agro-morphological characters, farmer selection and maintenance.

11. The genetics structure of crop landraces and the challenge to conserve them *in situ* on-farms, seed systems: formal *vs* informal.
12. Institutional frameworks for the implementation of on-farm conservation.
13. Identification of target crops, site selection, community sensitization,
14. Participatory plant breeding, sampling, structuring, documentation and presenting information for action plans.
15. Increasing crop genetic diversity's competitiveness for farmers, improvising the material and farmers 'access to genetic materials, increasing consumer demand.
16. The role of policy, deciding on an appropriate initiative, evaluating benefit-enhancement options.
17. The role of Geographical Indications (GI) in agri-horticultural crops.

PRACTICAL SCHEDULE

1-5. Floristic surveys and inventory (wild species in nature reserves and crop species in traditional agro-ecosystems), questionnaire preparation;

5-10.Visit to commercial units processing native crops, and to on farm fields and to community seed banks in villages;

11. The genetic structure of cereal landraces and the challenge to conserve them *in situ* on-farm at selected sites.
12. The genetic structure of pulses landraces and the challenge to conserve them *in situ* on-farm at selected sites.
13. The genetic structure of oilseeds landraces and the challenge to conserve them *in situ* on-farm at selected sites.
14. The genetic structure of fibre and forage crops landraces and the challenge to conserve them *in situ* on-farm at selected sites.
15. Visit to in-situ conservation sites - biosphere / national park /on-farm sites
16. Visit to ex-situ conservation sites - seed gene bank and botanical survey of India
17. **Practical Examinations**

LEARNING OUTCOME

Students will understand the current status of in-situ onfarm conservation

SUGGESTED READING

1. Brush SB 1999. *Genes in the field: On-farm Conservation of Crop Diversity*. Lewis Publishers, Boca Raton, Florida, USA.

2. 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
3. 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.
4. Jarvis D, Hodgkin T, Brown AHD, Tuxill JD, Loìpez Noriega I, Smale M, Shtapit B, Samper S. 2016. Crop Genetic Diversity in the Field and on the Farm. Principles and Applications in Research Practices. Yale Agrarian Studies Series. Bioversity International, Maccarese.
5. Swiss Agency for Development and Cooperation (SDC), Bern/ Yale University Press, New
6. 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.
7. 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.
8. Vernoy, R, Shrestha P and Sthapit B. 2015. *Community Seed Banks: Origins, Evolution and Prospects*. Oxford, Routledge.

MBB 602 GENOME ENGINEERING 3+0

AIM OF THE COURSE

To discuss the specialized topics and advances in field of genetic engineering and their application in crop improvement.

THEORY

Unit I: Genetic Engineering for Stress Resistance

Conventional versus non-conventional methods for crop improvement; Present status in plant genetic engineering. Genetic engineering for resistance against abiotic (drought, salinity, flooding, temperature, etc) and biotic (insect pests, fungal, viral and bacterial diseases, weeds, etc) stresses; herbicide resistance.

Unit II: Genetic Engineering for Yield and Quality

Genetic Engineering for increasing crop productivity by manipulation of photosynthesis, nitrogen fixation and nutrient uptake efficiency; Genetic engineering for quality improvement - protein, essential amino acids, fatty acid compositions, vitamins, mineral nutrients; shelf life of fruits and vegetables; Genetic engineering for pollination control - male sterility in plants; phytoremediation; engineering bioenergy crops.

Unit III: Recent Advances in Genetic Engineering

Recent developments in transgenic technology - methods to improve the efficiency of regeneration of transgenic plans; Marker-free transgenic development strategies; RNAi-based gene silencing. *Cis*-genic and intragenic plants; Regulated and tissue-specific expression of transgenes for crop improvement; Gene stacking; Pathway engineering; High throughput phenotyping of transgenic plants Transient expression system using viral vectors – Molecular pharming; Synthetic biology.

Unit IV: Genome Editing

Genome editing: principles and methods, CRISPR *Cas*9, CRISPR *Cpf*1 system, Development of genome edited plants – indels and base substitution mutation; gene replacement and transgenic plants with precise integration; prime editing, gene drive and other recent developments; regulation of genome edited plants.

Unit V: Biosafety Studies

Environmental issues associated with transgenic crops; Food and feed safety issues associated with transgenic crops; Risk assessment of transgenic food crops; Recent development in biosafety regulation – genome edited plants (SDN1, SDN2 and SDN3 plants); confined field trials.

LECTURE SCHEDULE

1. An over-view on the present status of Genetically Engineered crops; advantages of genetic engineering over conventional methods of crop improvement; Advances in vector construction methods
2. Genetic engineering for insect resistance, Bt mediated insect resistance
3. Improving Bt expression in plants; case studies
4. Insect resistance genes of plant and other origin
5. Genetic engineering for fungal disease resistance; case studies
6. Genetic engineering for bacterial disease resistance; case studies

7. Genetic engineering for viral disease resistance; case studies
8. Engineering crops for abiotic stress resistance
9. Abiotic resistance; case studies
10. Engineering for herbicide tolerance
11. Engineering photosynthesis in plants
12. Genetic Engineering Approaches to Improving Nitrogen Use Efficiency/N-fixation
13. Genetic engineering for nutritional quality – protein
14. Genetic engineering for nutritional quality – mineral & vitamins
15. Genetic engineering for nutritional quality – fatty acid composition
16. Genetic engineering for nutritional quality – starch composition
17. Genetic Engineering bioenergy crops
18. Genetic engineering for quality –shelf life
19. Genetic engineering for pollination control - male sterility in plants
20. Genetic engineering for phytoremediation
21. Methods to improve efficiency of regeneration in transgenic plants
22. Strategies for development of Marker-free transgenic plants
23. RNAi mediated gene silencing in plants and applications for quality improvement
24. Applications of RNAi technology for pest and disease resistance

25.&26. Synthetic biology; synthetic food

27. *Cis*-genesis and intragenesis
28. *Cis*-genesis *vs* transgenesis; examples
29. Regulated and tissue-specific expression of transgenes
30. Gene stacking and Pathway engineering – case studies
31. High throughput phenotyping of transgenic plants
32. Molecular pharming in different systems
33. Plant Molecular pharming for pharmaceutical proteins
34. Transient expression of recombinant proteins using viral vectors
35. Advances in chloroplast transformation
36. Production of therapeutic proteins in chloroplasts
37. Targeted genome modification – basics; ZFN and TALEN
38. CRISPR technology
39. Advances in CRISPR technology
40. Applications of genome editing technology – Yield and quality
41. Applications of genome editing technology – stress tolerance
42. Gene drive and its application in insect control
43. Biosafety issues; Environment and food safety concerns of transgenic plants
44. Food safety concerns of transgenic plants
45. Principles of Risk assessment; Problem formulation methodology for risk assessment
46. Environmental risk assessment
47. Risk assessment for food and feed safety
48. Biosafety regulations at national level; regulatory set up in India; GM detection
49. Conduct of confined field studies
50. National and international regulations
51. Regulation of transgenic crops and genome edited plants in India and in other countries

LEARNING OUTCOME

By the end of this course, students will be able to describe rapid advances that have taken place in the field of transgenic plant production and genome editing and explain how these tools and techniques are used to genetically improved crop varieties.

SUGGESTED READINGS

1. Handbook of Plant Biotechnology, 2 volume set, Edited by Christou P and Klee H. Wiley publisher, 2004, 1488 pages.
2. Plant Biotechnology- The genetic manipulation of plants by Authors, Slater et al., 2008, Oxford University Press, 376 pages.
3. Biotechnologies of Crop Improvement, Volume 2, Transgenic Approaches. Edited by Gosal SS and Wani SH, Springer International Publishing, 2018, 485 pages.
4. Stewart Jr, C. N. (2016). Plant biotechnology and genetics: principles, techniques, and applications. John Wiley & Sons.

SUGGESTED WEBSITES

1. https://www.isaaa.org/kc/default.asp
2. https://www.isaaa.org/gmapprovaldatabase/default.asp
3. https://www.oecd.org/environment/genome-editing-agriculture/
4. https://www.isaaa.org/resources/genomeediting/default.asp

MBB 603 OMICS AND MOLECULAR BREEDING (3+0)

AIM OF THE COURSE

To impart knowledge in the upcoming areas of omic technologies and to understand the recent developments in Molecular Breeding technologies.

THEORY

Unit I

Protein and nucleic acid sequencing, various methods of sequencing including automated sequencing and microarrays, Whole Genome Sequence Analysis. Genomics – methods of analysis and application, Comparative genomics, functional genomics, nutrigenomics, transcriptomics, gene identification, gene annotation, pairwise and multiple alignments, application of genomics, quantitative PCR, SAGE, MPSS, microarray, role of bioinformatics in functional genomics.

Unit II

Proteome technology, 2D-PAGE, MSMS, MALDI-TOF, comparative proteomics and structural proteomics. Metabolomics and ionomics, Elucidation of metabolic pathways, Sample preparation for metabolomics. Techniques involved in metabolite identification-LCMS, NMR, FTIR, MS. Metabolomics in biotic and biotic stress in crop plants, SPE, SPME, metabolic pathway engineering and its application, Concept and application of ionome and ionomics. Genotyping; Biochemical and Molecular markers; Morphological, biochemical and DNA-based markers (RFLP, RAPD, AFLP, SSR, SNPs, ESTs, etc.), Functional markers; Mapping populations (F2s, back crosses, RILs, NILs and DH);

Unit III

Molecular mapping and tagging of agronomically important traits; Statistical tools in marker analysis. 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 IV

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. Recombinant DNA technology, transgenes, method of transformation, selectable markers and clean transformation techniques, vector-mediated gene transfer, physical methods of gene transfer.

Unit V

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.

Lecture schedule:

1. Recent advances in Protein and nucleic acid sequencing
2. Various methods of sequencing including automated sequencing
3. Microarrays and its role in crop improvement
4. Whole Genome Sequence Analysis
5. Genomics – methods of analysis and application
6. Comparative genomics and functional genomics
7. Nutrigenomics and transcriptomics
8. Gene identification and gene annotation
9. Pairwise and multiple alignments
10. Application of genomics in crop improvement
11. Quantitative PCR and SAGE
12. MPSS and microarray
13. Role of bioinformatics in functional genomics
14. Proteome technology and 2D-PAGE
15. MSMS and MALDI-TOF
16. Comparative proteomics and structural proteomics
17. Metabolomics and ionomics, Elucidation of metabolic pathways
18. Sample preparation for metabolomics
19. Techniques involved in metabolite identification- LCMS, NMR, FTIR, MS
20. Metabolomics in biotic and biotic stress in crop plants, SPE, SPME
21. Metabolic pathway engineering and its application
22. Concept and application of ionome and ionomics
23. Genotyping; Biochemical and Molecular markers; Morphological, biochemical markers
24. DNA-based markers (RFLP, RAPD, AFLP, SSR, SNPs, ESTs, *etc*.)

25.&26. Functional markers and its role in crop improvement

27. Mapping populations (F2s, back crosses, RILs, NILs and DH)
28. Molecular mapping and tagging of agronomically important traits
29. Statistical tools in marker analysis
30. Allele mining and its role in crop improvement
31. Marker-assisted selection for qualitative and quantitative traits
32. QTLs analysis in crop plants
33. Marker-assisted backcross breeding for rapid introgression
34. Genomics- assisted breeding
35. Generation of EDVs and Gene pyramiding
36. Introduction to Comparative Genomics and large-scale genome sequencing strategies
37. Human genome project and Arabidopsis genome project
38. Rice genome project; Comparative genomics tools
39. Introduction to proteomics and 2D gel electrophoresis
40. Chromatography and sequencing by Edman degradation and mass spectrometry
41. Endopeptidases; Nanotechnology and its applications in crop improvement
42. Recombinant DNA technology, transgenes, method of transformation, selectable markers and clean transformation techniques
43. Vector-mediated gene transfer, physical methods of gene transfer

44. Production of transgenic plants in various field crops: cotton, wheat, maize, rice, soybean, oilseeds, sugarcane, etc. and commercial releases
45. Biotechnology applications in male sterility/ hybrid breeding, molecular farming
46. Application of Tissue culture in molecular breeding
47. MOs and related issues (risk and regulations); GMO; International regulations, biosafety issues of GMOs
48. Regulatory procedures in major countries including India, ethical, legal and social issues
49. Intellectual property rights
50. Introduction to bioinformatics: bioinformatics tools
51. Biological data bases (primary and secondary), implications in crop improvement

LEARNING OUTCOME

The student will be able to know about different aspects of omics and molecular breeding for crop improvement

SUGGESTED READINGS

1. Alonso JM, Stepanova AN. 2015. Plant Functional Genomics: Methods and Protocols. Springer.
2. Chopra VL, Sharma RP, Bhat SR and Prasanna BM. 2007. Search for New Genes. Academic Foundation, New Delhi.
3. 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.
4. Primose SB and Twyman RM. 2006. Principles of Gene Manipulation and Genomics. 7th Ed. Wiley-Blackwell Publishing.
5. Sambrook J and Russel D. 2001. Molecular Cloning - a Laboratory Manual. 3rd Ed. Cold Spring Harbor Laboratory Press.
6. Singh BD. 2005. Biotechnology: Expanding Horizons. Kalyani Publishers, New Delhi.
   Somers DJ, Langridge P, Gustafson JP. 2009. Plant Genomics: Methods and Protocols. Springer
7. Tomita, M. and Nishioka, T. (Eds.). 2006. Metabolomics: the frontier of systems biology. Springer Science and Business Media
8. Horst, L. and Wenzel, G. (Eds.). 2007. Molecular marker systems in plant breeding and crop improvement (Vol. 55). Springer Science and Business Media.

MBB 604 COMMERCIAL PLANT TISSUE CULTURE 3 (3+0)

AIM OF THE COURSE

To impart knowledge in the latest and recent technologies in commercial plant tissue culture in agricultural and horticultural crops.

THEORY

Unit I

Introduction to and background of plant tissue culture: Past, current, and future aspects. Tissue culture media; Plant hormones and morphogenesis; Direct and indirect organogenesis; Direct and indirect somatic embryogenesis; Applications of plant tissue culture; National certification and Quality management of TC plants; Genetic Fidelity testing and Virus indexing methods – PCR, ELISA. Role of plant tissue culture in pharmaceuticals and secondary metabolites production. Micropropagation of field and ornamental crops; Micro-propagation of commercially important plant species; plant multiplication, hardening, and transplantation.

Unit II

Genetic fidelity; scaling up and cost reduction; bioreactors; synthetic seeds; management and marketing. Virus elimination by meristem culture, meristem tip culture and micro-grafting; Androgenesis and gynogenesis - production of androgenic and gynogenic haploids - diploidization; A generalized method for haploid production through anther culture, Factors affecting anther culture, Production of doubled haploid plant, Identification of haploid plants, Application of anther culture in crop improvements and Progress in the haploid production through anther culture.

Unit III

Wide hybridization - embryo culture and embryo rescue techniques; Embryo rescue: A potential tool for improvement of economically important crops. Embryo culture technique and applications of embryo culture, Ovule, ovary culture and endosperm culture. Protoplast culture - isolation and purification; Protoplast fusion; Somatic hybridization - Production of Somatic hybrids and Cybrids; Large-scale cell suspension culture. Production of alkaloids and other secondary metabolites - techniques to enhance secondary metabolite production.

Unit IV

Somaclonal and gametoclonal variations – causes and applications; Callus culture and *in vitro* screening for stress tolerance; *in vitro* germplasm storage and cryo-preservation. Commercial Tissue Culture: Case studies and success stories, Market assessment; project planning and preparation, economics, government policies. Direct DNA delivery – chemical mediated electroporation and particle bombardment. Vectors and transgene design - Promoters and Marker genes. Chloroplast transformation. Development of marker-free plants. Analysis of transgenic plants – molecular and Biochemical assays, genetic analysis - Identification of gene integration site - Advance methods – *cis* genesis, intragenesis and targeted genome modification – ZFN, TALENS and CRISPR.

Unit V

Application of transgenic technology. Field studies with transgenic crops; Environmental issues associated with transgenic crops; Food and feed safety issues associated with transgenic crops; Risk assessment of transgenic food crops. Value-addition

by transformation; development, production and release of transgenic plants; patent, bio-safety, regulatory, environmental and ethical issues; management and commercialization. Project planning and preparation, economics (entrepreneurship, cost profit ratio), government policies (incubators, different facilitation projects, loan opportunities). Some case studies on success stories on commercial applications of plant tissue culture.

LECTURE SCHEDULE

1. Introduction to and background of plant tissue culture: Past, current, and future aspects
2. Tissue culture media
3. Plant hormones and morphogenesis
4. Direct and indirect organogenesis
5. Direct and indirect somatic embryogenesis
6. Applications of plant tissue culture
7. National certification and Quality management of TC plants
8. Genetic Fidelity testing and Virus indexing methods – PCR, ELISA
9. Role of plant tissue culture in pharmaceuticals and secondary metabolites production
10. Micropropagation of field and ornamental crops
11. Micro-propagation of commercially important plant species; plant multiplication, hardening and transplantation
13. Genetic fidelity; scaling up and cost reduction
14. Bioreactors
15. Synthetic seeds; management and marketing
16. Virus elimination by meristem culture, meristem tip culture and micro-grafting
17. Androgenesis and gynogenesis - production of androgenic and gynogenic haploids - diploidization
18. A generalized method for haploid production through anther culture. Factors affecting anther culture
19. Production of doubled haploid plant and Identification of haploid plants
20. Application of anther culture in crop improvements
21. Progress in the haploid production through anther culture.
22. Wide hybridization - embryo culture and embryo rescue techniques
23. Embryo rescue: A potential tool for improvement of economically important crops
24. Embryo culture technique and applications of embryo culture

25.&26. Ovule, ovary culture and endosperm

27. Protoplast culture - isolation and purification; Protoplast fusion
28. Somatic hybridization - Production of Somatic hybrids and Cybrids
29. Large-scale cell suspension culture
30. Production of alkaloids and other secondary metabolites
31. Techniques to enhance secondary metabolite production
32. Somaclonal and gametoclonal variations – causes and applications
33. Callus culture and *in vitro* screening for stress tolerance
34. *in vitro* germplasm storage and cryo-preservation
35. Commercial Tissue Culture: Case studies and success stories
36. Market assessment of Tissue Culture
37. Project planning and preparation of Tissue Culture Unit

38. Economics, government policies related to Establishment Tissue Culture Unit
39. Direct DNA delivery – chemical mediated electroporation
40. Particle bombardment; Vectors and transgene design - Promoters and Marker genes.
41. Chloroplast transformation. Development of marker-free plants.
42. Analysis of transgenic plants – molecular and Biochemical assays, genetic analysis - Identification of gene integration site
43. Advance methods – *cis* genesis, intragenesis and targeted genome modification – ZFN, TALENS and CRISPR.
44. Application of transgenic technology
45. Field studies with transgenic crops; Environmental issues associated with transgenic crops
46. Food and feed safety issues associated with transgenic crops; Risk assessment of transgenic food crops.
47. Value-addition by transformation; development, production and release of transgenic plants
48. Patent bio-safety, regulatory, environmental and ethical issues; management and commercialization
49. Project planning and preparation, economics (entrepreneurship, cost profit ratio)
50. Government policies (incubators, different facilitation projects, loan opportunities).
51. Some case studies on success stories on commercial applications of plant tissue culture

LEARNING OUTCOME

The student will be able to know about important aspect commercial plant tissue culture in the improvement of the characters of field crops.

SUGGESTED READINGS

1. Razdan, M.K. 2003. Introduction to plant tissue culture, 2nd edition, Oxford publications group
2. Butenko, R.G. 2000. Plant Cell Culture University Press of Pacific Herman, E.B. 2008. Media and Techniques for Growth, Regeneration and Storage, Agritech Publications, New York, USA.
3. Bhojwani, S.S and Dantu P. 2013. Plant Tissue Culture – An Introductory Text. Springer Publications.
4. Gamborg, O.L and G.C. Philips (eds.). 2013. Plant Cell, Tissue and Organ culture- Lab Manual. Springer Science & Business media.

SST 601 HYBRID SEED PRODUCTION TECHNOLOGY (2+1)

AIM OF THE COURSE

To provide students a comprehensive knowledge and practical exposure on hybrid seed production techniques in agricultural and horticultural crops.

THEORY

Unit I

Introduction - history, scope and importance of hybrid development; international and national scenario of seed industry - popular public sector hybrids in various crops; heterosis - definition, expression and types - utilization of heterosis in hybrid development, hybrid vigour *vs* seed vigour.

Unit II

Types of hybrids - inter-specific and intra-specific, hybrids, single, double, three way cross, double top cross and apomictic hybrids; generation system of seed multiplication in hybrids. development and maintenance of inbred lines - male sterile lines, maintainer lines and fertility restorer lines; transgenic hybrids - principles and method of development.

Unit III

Breeding tools - genetic mechanism - types of male sterility - CMS, GMS, CGMS, TGMS and PGMS - barnase and barstar system - pistillateness and self-incompatibility; manual manipulation of male sterility - emasculation and pollination, detasseling, gametocides - mode of action; non synchronization of flowering - methods to achieve synchrony; planting design and supplementary pollination methods.

Unit IV

Techniques of hybrid seed production in major agricultural crops - Cereals (Rice and Maize), Millets (Sorghum and Pearl Millet), Pulses (Red Gram), Oilseeds (Sunflower, Castor and Mustard) and Cotton.

Unit V

Hybrid seed production techniques in horticultural crops - Tomato, Brinjal, Chilli, Bhendi, Onion, Bitter Gourd, Bottle Gourd, Ridge Gourd, Cucumber, Melons, Cabbage, Cauliflower, Papaya, Coconut

PRACTICALS

Floral biology - planting design - synchronization methods - supplementary pollination - field inspection and assessment of field standards in hybrid seed production plots of Rice, Maize, Sorghum, Pearl Millet, Redgram, Cotton, Sunflower, Castor, Cucurbits and Tomato - detasseling in maize - emasculation and pollination in cotton and vegetable crops - visit to hybrid seed production fields - determination of cost benefit of hybrid seed production - visit to seed industry.

LECTURE SCHEDULE

1. Introduction, history, scope and importance of hybrid development
2. International and National scenario of seed industry and hybrids in various crops
3. Definition, expression and types of heterosis
4. Utilization of heterosis in hybrid development, hybrid vigour *vs* seed vigour

5. Inter and intra-specific hybrids, single, double, three way and double top cross and apomictic hybrids
6. Generation system of seed multiplication in hybrids
7. Development and maintenance of inbred lines, male sterile lines, maintainer lines and fertility restorer lines
8. Breeding tools for development of hybrids - CMS, GMS, CGMS, TGMS, PGMS
9. Barnase and barstar system, pistillateness and self-incompatibility in hybrid development
10. Manual creation of male sterility - emasculation and pollination, detasseling and gametocides
11. Principles and method of development of transgenic hybrids
12. Non-synchronization of flowering and methods to achieve synchrony
13. Planting design and supplementary pollination in hybrid seed production
14. Techniques of hybrid seed production in rice
15. Techniques of hybrid seed production in maize
16. Techniques of hybrid seed production in sorghum
17. &18. Techniques of hybrid seed production in pearl millet
19. Techniques of hybrid seed production in red gram
20. Techniques of hybrid seed production in sunflower
21. Techniques of hybrid seed production in castor
22. Techniques of hybrid seed production in mustard
23. Techniques of hybrid seed production in cotton
24. Hybrid seed production techniques in tomato
25. Hybrid seed production techniques in brinjal
26. Hybrid seed production techniques in chilli
27. Hybrid seed production techniques in bhendi
28. Hybrid seed production techniques in onion
29. Hybrid seed production techniques in bitter gourd, bottle gourd and ridge gourd
30. Hybrid seed production techniques in cucumber and melons
31. Hybrid seed production techniques in cabbage
32. Hybrid seed production techniques in cauliflower
33. Hybrid seed production techniques in papaya
34. Hybrid seed nut production techniques in coconut

PRACTICAL SCHEDULE

1. Study on floral biology of rice, maize, sorghum, pearl millet,
2. Study on floral biology of redgram, sunflower, castor and cotton
3. Study on floral biology of tomato, brinjal, chillies and bhendi
4. Study on floral biology of cucurbitaceous crops, papaya and coconut
5. Practicing planting design in rice, maize, pearl millet and red gram
6. Practicing planting design in sunflower, cotton and bhendi
7. Practicing planting design in tomato, brinjal and chillies
8. Practicing emasculation and pollination in cotton and vegetable crops
9. Study on synchronization methods in rice, sorghum, pearl millet and sunflower
10. Practicing supplementary pollination in rice and sunflower
11. Practicing field inspection in hybrid seed production plots
12. Assessment of field standards for hybrid seed production in different crops
13. Visit to hybrid seed production fields
14. Visit to potato seed production plot
15. Determination of cost benefit of hybrid seed production
16. Visit to seed industry

17. **Final practical examination**

SUGGESTED READINGS

1. McDonald, M. F. and Copeland, L. O. 2012. Seed Production: Principles and Practices. Springer Science & Business Media, Boston, United States.
2. Basra, A. 1999. Heterosis and Hybrid Seed Production in Agronomic Crops. CRC Press., Florida, United States.
3. Singhal, N. C. 2003. Hybrid Seed Production. Kalyani Publishers., New Delhi, India.
4. Vanangamudi, K., Prabhu, M., Kalaivani, S., Bhaskaran, M and Manonmani, V. 2010. Vegetable hybrid seed Production and Management. Agrobios., Jodhpur, India.
5. Krishnan, M. 2012. Plant breeding and Hybrid Seed Production. Domin and Publishers & Distributors., New Delhi, India.
6. Maiti, R. K., Sarkar, N.C. and Singh, V.P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios., Jodhpur, India.
7. Singhal, N. C. 2003. Hybrid Seed Production in Field Crops. Kalyani Publications, New Delhi.
8. Frankel, R and Galun, E. 1977. Pollination Mechanisms, Reproduction and Plant Breeding. Springer Verlag, New York.
9. Chhabra, A. K. 2006. Practical Manual of Floral Biology of Crop Plants. Department of Plant Breeding, CCSHAU, Hisar.
10. Agarwal, R. L. 2012. Seed Technology. 3rd Ed. Oxford & IBH Publishers, New Delhi. Dar, S. H. 2018. Methods of Hybrid Seed Production in Major Crops. Educreation Publishing, Chhattisgarh.
11. Joshi, A. K. and Singh, B. D. 2004. Seed Science and Technology. Kalyani Publishers, New Delhi.
12. Kulkarni, G. N. 2011. Principles of Seed Technology. Kalyani Publishers, New Delhi.
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SST 604 GENETIC PURITY AND DUS TESTING (2+1)

AIM OF THE COURSE

To impart knowledge on various methods of genetic purity assessment and DUS testing for protection of plant varieties.

THEORY

Unit I

Genetic purity - importance - factors influencing genetic purity; genetic / cultivar purity test -objectives, principles and methods - green house, field plot / grow-out test; laboratory tests -seed and seedling growth tests, anthocyanin pigmentation; chemical and biochemical methods -phenol, NaOH, KOH, peroxidase and fluorescence tests - chromatography techniques to detect secondary compounds.

Unit II

Electrophoretic analysis of proteins and isozymes; DNA finger printing methods - RAPD, AFLP, SSR and SNP; 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&FR) Act, 2001 - objectives, salient features, farmer's rights, breeder's rights, researcher's rights - PPV&FR 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 and 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.

Unit V

Assessment of DUS characters of major crops based on morphological, biochemical and molecular markers - rice, wheat, maize, sorghum, pearl millet, black gram, green gram, red gram, cowpea, sunflower, groundnut, castor, mustard, cotton, tomato, brinjal, chilli, bhendi, ridge gourd, bitter gourd, pumpkin, onion, potato, cabbage, cauliflower; statistical procedure - computer software for DUS data analysis; guidelines for registration of germplasm - impact of plant variety protection on seed industry growth.

PRACTICALS

Genetic purity assessment based on seed characters - seedling growth tests and anthocyanin pigmentation - phenol, modified phenol, NaOH, KOH, peroxidase and fluorescence tests -chromatography analysis of secondary compounds - electrophoretic analysis of seed protein and isozymes - DNA fingerprinting using PCR techniques - DUS characterization for different crops -rice, millets, pulses, oilseeds, cotton, vegetables- statistical analysis and interpretation of data - cluster analysis of DUS traits - chemical and biochemical tests applicable for DUS testing - visit to DUS test centres.

LECTURE SCHEDULE

1. Importance of genetic purity and factors responsible for genetic purity maintenance
2. Genetic / cultivar purity test - objectives, principles and methods
3. Green house and field plot / grow-out test for genetic purity assessment
4. Genetic purity assessment through laboratory tests - seed and seedling growth tests and anthocyanin pigmentation
5. Genetic purity assessment by chemical and biochemical methods - phenol, NaOH, KOH, peroxidase and fluorescence tests
6. Chromatography techniques to detect the secondary metabolites
7. Electrophoretic analysis of proteins and isozymes
8. DNA finger printing methods for cultivar purity - RAPD, AFLP, SSR and SNP
9. Computer based machine vision technique and image analysis for varietal identification
10. Genesis of plant variety protection (PVP) and GATT agreement on PVP
11. International Union for Protection of New Varieties of Plants (UPOV) and its role on PVP
12. Protection of Plant Varieties and Farmer's Rights (PPV&FR) Act, 2001 - objectives and salient features
13. Farmer's rights, breeder's rights and researcher's rights in PPV&FR Act
14. Salient features of PPV&FR Rules, 2003
15. Criteria for protection of new varieties of plants - Distinctness, Uniformity and Stability
16. DUS testing - principles and procedures, guidelines, sample size, test duration and testing option
17. &18. Varieties under PVP - new variety, varieties of common knowledge, extant variety and essentially derived variety
19. Collection of reference samples and grouping of varieties
20. Types of characters and characterization of varieties in DUS testing
21. Study on DUS characters for rice, wheat, maize
22. Study on DUS characters for sorghum and pearl millet
23. Study on DUS characters for black gram, green gram and red gram
24. Study on DUS characters for cowpea

2.5 Study on DUS characters for sunflower, groundnut, castor and mustard

26. Study on DUS characters for sugarcane and cotton
27. Study on DUS characters for tomato, brinjal,
28. Study on DUS characters for chilli and bhendi
29. Study on DUS characters for ridge gourd, bitter gourd and pumpkin
30. Study on DUS characters for onion and potato
31. Study on DUS characters for cabbage and cauliflower
32. Statistical procedure and computer software for DUS data analysis
33. Guidelines for registration of germplasms and varieties
34. Impact of plant variety protection on seed industry

PRACTICAL SCHEDULE

1. Genetic purity assessment of varieties based on seed characters
2. Genetic purity assessment based on seedling growth tests and anthocyanin pigmentation
3. Genetic purity assessment by chemical tests - phenol, modified phenol, NaOH and KOH tests
4. Analysis of secondary compounds using chromatography
5. Electrophoretic analysis of seed protein and isozymes for cultivar purity
6. DNA fingerprinting using PCR techniques
7. DUS characterization of rice and millets

8. DUS characterization of pulses and oilseeds
9. DUS characterization of cotton and sugarcane
10. DUS characterization of vegetable crops
11. DUS characterization of fruit and flower crops
12. DUS characterization of tree species
13. Statistical analysis and interpretation of data
14. Cluster analysis of DUS varieties
15. Visit to DUS test centres of agricultural and horticultural crops
16. Visit to DUS test centres of tree species
17. **Final practical examination**

SUGGESTED READINGS

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3. Choudhary, D. R. 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.
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PP 602 SIGNAL PERCEPTIONS AND TRANSDUCTION AND REGULATION OF PHYSIOLOGICAL PROCESSES (2+0)

AIM OF THE COURSE

Main objective of this course is to provide comprehensive exposure on different signaling events and associated cellular changes in plants. The course will include lectures on the signalling mechanisms employed by plants to perceive and transduce environmental signals.

THEORY

Unit I: Signaling and Components of Signal Perception and Transduction

Introduction to signaling - Signal, signal types - long (diffusible) and short (contact) range signaling. Components of signaling - Two component sensing system - Upstream components: ligand - receptor concept - types of ligands - nature of ligands - Types of receptors - Cell surface trans-membrane receptors- GPCRs, Receptor Tyrosine Kinases (RTKs), Receptor Serine Threonine kinases (RSTKs), Receptor-Like Kinases (RLKs). Downstream components - primary, secondary signaling components - Signal transfer phosphor-relay and generation of secondary signaling components and activation of TFs or enzymes - G-proteins, second messengers-Cyclic AMP, Adenylate, cyclase cascade, cyclic GMP, calcium-calmodulin-kinases; effector molecules (transcription factors).

Unit II: Hormonal Signaling

Hormone binding receptors – Perception and transduction process - Effector molecules and gene expression. Specific signaling pathways of Auxins, Cytokinin, Gibberellins, Ethylene, ABA, Brassinosteroids, Salicylic Acid, Strigolactones, polyamines, Jasmonic acid, etc. which lead to formative effects. Cross talk in the signaling of different hormones-significance of studies with hormone action mutants.

Unit III: Light Signaling

Perception of light - Pigments involved - activation of phytochrome/cryptochrome (study of mutants). Light signal transduction - Multiple signaling cascades - identification of signaling components through mutant analysis - changes in gene expression.

Unit IV: Abiotic Stress Signaling and Nutrient Signaling

Abiotic Stress Signaling: Sensing of environmental factors (Temperature-Osmotic-Ionic stress), Activation of specific molecules and secondary messengers, activation of downstream components leading to stress gene expression. Case studies with different abiotic stresses. Retrograde signaling. Nutrient Signaling: Signaling cascade with respect to nitrogen fixation, nitrogen, phosphorus and potassium uptake and translocation.

Unit V: Signaling during developmental Events and in Plant Defense Responses

Signaling cascades during developmental events - Signaling during seed germination, Leaf senescence, fruit development and ripening, Tuberization, Sugar signaling. General signaling mechanisms in plant defense responses – Biotic stress – Pathogens and Insects - Role of salicylic acid, jasmonic acid and reactive oxygen species. Cross talk signaling - Stress matrix under field conditions - Cross talk between abiotic stresses – Biotic and abiotic stress signaling networks.

LECTURE SCHEDULE

1. Introduction to signaling in plants in physiological processes

2. Signal, signal types - long (diffusible) and short (contact) range signaling.
3. Components of signaling - Two component sensing system-Upstream components: ligand - receptor concept - types of ligands - nature of ligands.
4. Types of receptors - Cell surface trans-membrane receptors-GPCRs, Receptor Tyrosine Kinases (RTKs), Receptor Serine Threonine kinases (RSTKs), Receptor-Like Kinases (RLKs).
5. Downstream components - primary, secondary signaling components-Signal transfer phosphor-relay and generation of secondary signaling components and activation of TFs or enzymes - G-proteins
6. Second messengers - Cyclic AMP, Adenylate, cyclase cascade, cyclic GMP, calcium-calmodulin-kinases; effector molecules (transcription factors).
7. Second messengers-cyclic GMP, calcium-calmodulin-kinases; effector molecules (transcription factors).
8. Specific signaling pathways of Auxins leading to formative effects - Signal perception and transduction process - Receptors, secondary messengers, effectors and gene expression.
9. Specific signaling pathways of Cytokinins leading to formative effects-Signal perception and transduction process-Receptors, secondary messengers, effectors and gene expression.
10. Specific signaling pathways of Gibberellins leading to formative effects-Signal perception and transduction process-Receptors, secondary messengers, effectors and gene expression.
11. Specific signaling pathways of Ethylene leading to formative effects - Signal perception and transduction process - Receptors, secondary messengers, effectors and gene expression.
12. Specific signaling pathways of Abscisic acid leading to formative effects-Signal perception and transduction process-Receptors, secondary messengers, effectors and gene expression.
13. Specific signaling pathways of Brassinosteroids leading to formative effects-Signal perception and transduction process - Receptors, secondary messengers, effectors and gene expression.
14. Specific signaling pathways of Salicylic acid, Jasmonic acid, Strigolactones & Polyamines leading to formative effects - Signal perception and transduction process - Receptors, secondary messengers, effectors and gene expression.
15. Cross talk in the signaling of different hormones leading to specific physiological responses in plants – Morphogenesis-Apical meristem, root formation, flower induction
16. Significance of hormone action mutants in elucidating activation of upstream and downstream components leading to gene expression.
17.&18. Perception of light and pigments involved in perception
19. Phytochrome/cryptochrome-activation-identification of signaling components through mutant studies
20. Light signal perception and transduction-Phototropins and ultraviolet light-Signaling cascades-identification of signaling components through mutant analysis-changes in gene expression.
21. Water stress: Signal perception and transduction: Activation of specific molecules, secondary messengers and downstream components leading to stress gene expression-case studies.
22. Temperature stress: Signal perception and transduction: Activation of specific molecules, secondary messengers and downstream components leading to stress gene expression - case studies.

23. Osmotic-Ionic stress: Signal perception and transduction: Activation of specific molecules, secondary messengers and downstream components leading to stress gene expression - case studies.
24. Cross talk between abiotic stress signaling in plants
25. Retrograde signaling-Signal perception and transduction-Activation of specific molecules, secondary messengers and downstream components leading to stress gene expression - case studies.
26. Nutrient signaling: Signaling cascade of nitrogen fixation
27. Signaling cascades of nitrogen, phosphorus and potassium uptake and translocation
28. Signaling cascades during developmental events-Signaling during seed germination, and Leaf senescence
29. Signaling cascades during developmental events-Fruit development and ripening
30. Signaling cascades during developmental events-Tuberization and Sugar signaling.
31. General signaling mechanisms in plant defense responses–Biotic stress–Pathogens and Insects.
32. Role of reactive oxygen species in plant defense signalling
33. Role of salicylic acid and jasmonic acid in plant defense signaling
34. Stress matrix under field conditions-Cross talk signaling-Biotic and abiotic stress signaling networks.

LEARNING OUTCOME

By the end of this course, the student will be able to:

1. Comprehend various signaling events and associated physiological changes in plants.
2. Understand the diverse roles of receptors, ligand receptor interaction and the role of secondary messengers in signal amplification leading to gene expression.

SUGGESTED READINGS

1. Annual Plant Reviews: Intracellular Signaling in Plants by Peter Hedden, Richard Napier, Zhenbiao Yang (Editor) 2008, Wiley-Blackwell (an imprint of John Wiley and Sons Ltd) ISBN-13: 9781405160025
2. Becraft, P.W., 2002. Receptor kinase signaling in plant development. Annual review of cell and developmental biology, 18(1), pp.163-192.
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27. Plant Signalling Networks: Methods and Protocols, by Dr.Zhi-Yong Wang, Springer, 2016, ISBN-13: 9781493961696
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51. Zhu, J.K., 2016. Abiotic stress signaling and responses in plants. Cell, 167(2), pp.313-324.

SUGGESTED WEBSITES

1. https://www.nature.com/subjects/plant-signalling
2. https://link.springer.com/book/10.1007/978-3-540-89228-1
3. https://www.mdpi.com/journal/plants/special_issues/nitric_oxide_sig
4. https://edurev.in/studytube/Lecture-15-

PP 604 PLANT PHENOMICS - NEXT GENERATION PHENOMICS PLATFORMS (2+0)

AIM OF THE COURSE

The course aims at providing cutting edge knowledge on the current progress made in various phenotyping techniques and approaches. The students will be versed with principles of various phenotyping approaches. The aim is to provide hands-on expertise in analysing trait diversity. Exposure will be provided on Non-invasive imaging technologies that drive the phenomics platforms. The course provides comprehensive exposure on recent developments in phenomics platforms imaging tools/techniques and recent trends in designing specific phenomics platforms e.g. drought studies/root phenotyping *etc*.

THEORY

Unit I: Concepts of Phenotyping and Physio-Morphological Traits Associated with Crop Performance

Definition of phenotyping - concepts of "phene and trait" – Genome-phenome relationship - GxE interaction on phenome. Overview of phenotyping needs to complement genomic resources - Specific traits associated with yield potential, stress adaptation (both biotic and abiotic stresses) - Need for high throughput precision phenotyping approaches.

Unit II: Features of Phenomic Platforms

Precision growth conditions, maintenance of light, temperature/VPD and RH to realize the potential crop growth response - Controlled environmental facilities for simulating challenging climatic conditions to phenotype diverse plant traits - Concept of sensors, diverse sensors - Utility of different sensors in precise quantification of environmental variables, soil moisture sensors - Imaging to capture plant traits, image acquisition - Automated big data access, processing etc.

Unit III: Types of Phenomic platforms

Types of phenomic platforms- Laboratory, Greenhouse and the field-based platforms - Platforms designed for specific needs *i.e*., root phenotyping, drought studies etc. - Crop specific phenotyping - Mobile and stationary platforms - Global trends in establishing major phenomics platforms and their characteristic features and impact.

Unit IV: Non-invasive Phenotyping Approaches

The concept of non-invasive capturing of plant growth and health. Imaging technologies - image acquisition, segmentation, and data analysis. The concept of non-invasive capturing of plant growth and health: Critical aspects of Visual, IR Thermal and Fluorescence - The concept of non-invasive capturing of plant growth and health: Critical aspects of NIR, Hyperspectral imaging - The concept of non-invasive capturing of plant growth and health: Development and validation of models for deriving relevant physiological traits from image phenome - Concepts of Plants to sensors and sensors to plants: Stationary and ground based tractor mounted sensors/imaging tools - Concepts of Plants to sensors and sensors to plants: Unmanned aerial vehicle (UAV) sensors - Concepts of Plants to sensors and sensors to plants: Machine learning and its integration to analyse ground and aerial based images.

Unit V: Applications of the Phenomics Platforms

Characterize the growth and stress response in contrasts to identify the relevance of adaptive trait - Characterizing the pre-released promising lines for productivity under defined

environmental variables – Phenotyping germplasm accessions, mapping populations for specific traits for mapping - Concept of Phenome Wide Association Studies (PWAS) - Genomic selection- Gene-based crop models to predict complex traits - Impact of phenomics platform, progress made - Case studies.

LECTURE SCHEDULE

1. Definition of phenotyping, and concepts of "phene and trait"
2. Genome-phenome relationship
3. G x E interaction on phenome
4. Overview of phenotyping needs to complement genomic resources
5. Specific physio-morphological traits associated with yield potential
6. Specific physio-morphological traits associated with stress adaptation (both biotic and abiotic stresses).
7. Need for high throughput precision phenotyping approaches for basic studies and to generate genetic and genomic resources.
8. Precision growth conditions, maintenance of light, temperature/VPD and RH to realize the potential crop growth response.
9. Controlled environmental facilities for simulating challenging climatic conditions to phenotype diverse plant traits.
10. Concept of sensors and diverse sensors
11. Utility of different sensors in precise quantification of environmental variables, soil moisture sensors.
12. Imaging to capture plant traits, image acquisition.
13. Automated big data access, processing etc.
14. Types of phenomic platforms- Laboratory, Greenhouse and the field-based platforms.
15. Platforms designed for specific needs *i.e*., root phenotyping, drought studies etc.,
16. Crop specific phenotyping
17. **&**18. Mobile and stationary platforms.
19. Global trends in establishing major phenomics platforms and their characteristic features and Impact.
20. The concept of non-invasive capturing of plant growth and health. Imaging technologies - image acquisition, segmentation, and data analysis.
21. The concept of non-invasive capturing of plant growth and health: Critical aspects of Visual, IR Thermal and Fluorescence.
22. The concept of non-invasive capturing of plant growth and health: Critical aspects of NIR, Hyperspectral imaging.
23. The concept of non-invasive capturing of plant growth and health: Development and validation of models for deriving relevant physiological traits from image phenome.
24. Concepts of Plants to sensors and sensors to plants: Stationery and ground-based tractor mounted sensors/imaging tools.
25. Concepts of Plants to sensors and sensors to plants: Unmanned aerial vehicle (UAV) sensors.
26. Concepts of Plants to sensors and sensors to plants: Machine learning and its integration to analyse ground and aerial based images.
27. Characterizing the growth and stress response in contrasts to identify the relevance of adaptive trait
28. Characterizing the pre-released promising lines for productivity under defined environmental variables
29. Phenotyping germplasm accessions, mapping populations for specific traits for mapping.
30. Concept of Phenome Wide Association Studies (PWAS)

31. Genomic selection based on PWAS
32. Gene-based crop models to predict complex traits.
33. Impact of phenomic platforms and progress made
34. Impact of phenomic platforms – case studies in cereals and pulses

LEARNING OUTCOME

By the end of this course, the student will be able to understand the current progress made in various phenotyping techniques and approaches.

SUGGESTED READINGS

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43. Bradshaw, J. E. (2017). Plant breeding: past, present and future. Euphytica, 213(3).
44. Lee, U., Chang, S., Putra, G. A., Kim, H., and Kim, D. H. (2018). An automated, high-throughput plant phenotyping system using machine learning-based plant segmentation and image analysis. PloS one, 13(4), e0196615.
45. Furbank, R. T., and Tester, M. (2011). Phenomics–technologies to relieve the phenotyping bottleneck. Trends in plant science, 16(12), 635-644.

SUGGESTED WEBSITES

1. https://www.plant-phenotyping.org/
2. https://www.appn.at/about/
3. https://www.frontiersin.org/articles/10.3389/fpls.2019.00714/full
4. https://spj.sciencemag.org/journals/plantphenomics/2021/9871989/

PP 605 EXPERIMENTAL TECHNIQUES TO CHARACTERIZE PLANT PROCESSES FOR CROP IMPROVEMENT (0+2)

AIM OF THE COURSE

Aim of this course is to provide exposure to phenotype very specific physiological processes which have direct relevance in crop improvement programmes. The course provides insight on recent techniques and methodologies on each of the major physiological processes like stress responses, photosynthetic process, hormone area, photo-morphogenesis and genomics aspects.

THEORY

Unit 1: Stress Responses

Thermal characters and surface reflectance as a measure of water status, Fluorescence to measure stability of photosystem, root characteristics, Oxidative stress induction and assessing the quantification of ROS, RCC's, RNS, lipid peroxidation, Water use efficiency quantification at leaf, plant level, surrogates for WUE, Tissue localization of ROS, RNS by qualitative staining and fluorescence-based methods.

Unit 2: Photosynthetic processes

Concept and approaches to assess of radiation utilization efficiency (RUE), Quantification of mesophyll and other diffusive resistances regulating photosynthesis. Carboxylation efficiency (light and CO_2 response curves), RuBisCo activation status

Unit 3: Signaling in plants

Photo and Thermo Morphogenesis: Photo receptors, light and temperature regulation of plant growth and flowering, Thermal time, heat units, GDD, Hormonal Response on Specific Plant Growth Processes and Quantification: Bioassays to assess the biological process regulated by hormones – new in-vivo assays, Promoter assays for hormone response-GUS/YFP/GFP based assays expression of hormone responsive genes, Recent analytical tools and techniques to quantify hormones – GC-MS, LC-MS, Capillary electrophoresis. Concept and approaches for speed breeding.

Unit 4: Nutrient Response

Acquisition and Quantification Recent advances in soil less cultures to study the nutrient response- Hydroponics/Aeroponics/Fogoponics, Non-invasive techniques to quantify nutrients – XRD (XRay Diffraction analysis) and hyper spectral reflectance.

Unit 5: Recent Approaches for Functional Genomics

In silico prediction of gene function, Flanking sequence identification in insertional (T-DNA/transposon) mutants, Concept of insertional mutagenesis and mutant experiments, Utilization of genetic resources for functional genomics – mutants and tilling, eco tilling, VIGS, RNAi, miRNA, Genome editing –CRISPR, Concept of chemical genomics for functional validation, Relevant molecular tools to assess gene expression or (to regulate the process and assign a function to gene), Multiple gene expression by Nano String technology, Cap analysis gene expression (CAGE) – to identify start point of transcription, Yeast hybrid interaction, Immunoprecipitation, Chip-PCR.

LECTURE SCHEDULE

1. Estimation of Water status by infrared thermometer
2. Estimation of Lipid Peroxidation

3. Measurement of loss of membrane permeability
4. Estimation of Relative Water Content (RWC)
5. Quantification/staining for hydrogen peroxide
6. Quantification/staining of super oxide radicle
7. Radiation use efficiency and light use efficiency
8. Assessing stress response by measuring Fluorescence parameters
9. Estimation of WUE by gravimetry method
10. Estimation of WUE at single leaf level
11. Estimation of WUE by Carbon isotope discrimination method
12. Quantification of RuBisCO
13. Measuring RuBisCO activity
14. Estimation of Carboxylation efficiency by light and CO_2 response curve
15. Estimation of auxins (indole 3 acetic acid or IAA)
16. Estimation of Gibberellins by Calorimetry
17. Bioassay for IAA & Gibberellins
18. Extraction and estimation of cytokinins by Chromotography
19. Bioassay of Cytokinin
20. Bioassay of ABA - Inhibition of α-amylase synthesis in barley endosperm
21. Estimation of Cytokinin and Abscissic Acid by ELISA
22. Estimation of Ethylene by Gas Chromotography
23. Nutrient response by hydroponics/aeroponics
24. Estimation of Nutrient by Flame photometry
25. Noninvasive techniques to quantify nutrient - XRD
26. GDD-Growing Degree Days analysis for major food crops
27. Studying the photoperiodism in plants: Light experiments
28. Light and temperature dependent germination
29. Recent advances in Sequencing
30. Basic techniques in cloning – Primer designing, PCR, gel electrophoresis and elution
31. Vectors: Cloning and expression vectors
32. Blue white screening for selection of transformants and recombinants
33. Gene silencing by VIGS for assessing function of key genes
34. Genome editing by CRISPR to functionally validate genes regulating key traits in plant

LEARNING OUTCOME

After completion of this course students are expected to develop practical skill and knowledge on various experimental techniques employed in crop improvement programme. Moreover, students will have experience with characterization of plant processes.

SUGGESTED READINGS

1. Costa, Miguel and Grant, Olga and Chaves M. 2013. Thermography to explore plant environment interactions. J. Experimental Botany 64. 10.1093/jxb/ert029.
2. Padhi Jyotiprakash and K Misra R and Payero Jose. 2009. Use of infrared thermography to detect water deficit response in an irrigated cotton crop.

3. Root Phenotyping for Drought Tolerance: A Review, Wasaya A, Zhang X, Fang Q and Yan Z. 2018. Agronomy 8, 241; doi: 10.3390/agronomy8110241.

4. Zhang Y, Menghong D and Zonghui Y. 2018. Methods for the detection of reactive oxygen species. Analytical Methods 10 (38): 4625-4638.

5. Maxwell K and Giles NJ. 2000. Chlorophyll fluorescence—a practical guide. Journal of Experimental Botany 51 (345): 659-668.

6. Sinclair TR and Muchow RC. 1999. Radiation use efficiency. In Advances in Agronomy 65:215-265. Academic Press, 1999.

7. Yopp John H, Louis Htin Aung, and George L. Steffens (eds). 1986. Bioassays and other special techniques for plant hormones and plant growth regulators." Plant Growth Regulator Society of America.

8. DeBlasio, Stacy L., Anne W. Sylvester, and Jackson D. 2010. Illuminating plant biology: using fluorescent proteins for high-throughput analysis of protein localization and function in plants. Briefings in Functional Genomics 9 (2): 129-138.

9. Ljung K, Sandberg G, Moritz T. 2010. Methods of Plant Hormone Analysis. Davies P.J. (eds) Plant Hormones. Springer, Dordrecht

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11. Jones Jr, Benton J. 2016. Hydroponics: a practical guide for the soilless grower. CRC press. Nir I. 1981. Growing plants in aeroponics growth system. In Symposium on Substrates in Horticulture other than Soils In Situ 126 435-448.

12. Watson MC. 2018. Fogponic plant growth system. U.S. Patent Application 15/974,356 filed December 27.

13. Van Maarschalkerweerd M and Søren H. 2015. Recent developments in fast spectroscopy for plant mineral analysis. Frontiers in Plant Science 6: 169.

14. Qian F, Hong H, Zhao L, Kukolich S, Yin K and Wang C. 2018. Visible and near-infrared reflectance spectroscopy for investigating soil mineralogy: a review. Journal of Spectroscopy.

15. Moe, Roar and Heins RD. 2000. Thermo-and photomorphogenesis in plants. Advances in Floriculture Research Report 6 : 52-64.

16. Watson A, Ghosh S, Matthew JW, Cuddy WS, Simmonds J, Rey MD et al. 2018. Speed breeding is a powerful tool to accelerate crop research and breeding. Nature Plants 4 (1): 23.

17. Kahl G and Khalid M (eds.). 2008. The handbook of plant functional genomics: concepts and protocols. John Wiley and Sons.

18. Alonso JM, Stepanova AN. 2015 (Eds.) Plant Functional Genomics, Methods and Protocols

19. Leister D. 2004. 1st Edition Plant Functional Genomics

20. Shan Q, Wang Y, Li J, Yi Z, Chen K, Liang Z, Zhang K et al. 2013. Targeted genome modification of crop plants using a CRISPR-Cas system. Nature Biotechnology 31 (8): 686.

21. Sadhukhan A and Sahoo L and Panda S. 2012. Chemical Genomics in Plant Biology. Indian Journal of Biochemistry and Biophysics. 49. 143-154.

22. Fung TH, WeiwenXue V, Koh SP, Chiu YM, Ng LP and Wong SC. 2017. NanoString, a novel digital color-coded barcode technology: current and future applications in molecular diagnostics. Expert review of molecular diagnostics 17 (1): 95-103.

23. Rimantas K, Kojima M, Nishiyori H, Nakamura M, Fukuda S, Tagami M, Sasaki D *et al*. 2006. CAGE: Cap analysis of gene expression." Nature Methods 3 (3): 211.

Ph.D

SOIL SCIENCE

Ph.D. Soil Science

Sl No.	Course code	Course Title	Cr. Hr.
I.	**Major courses (12 credits)**		
01	Soil 601	Recent trends in soil physics	2+0
02	Soil 602	Modern concept in soil fertility	2+0
03	Soil 603*	Physical chemistry of soil	2+0
04	Soil 604*	Soil genesis and micromorphology	2+0
05	Soil 605	Bio-chemistry of soil organic matter	2+0
06	Soil 606	Soil resource management	3+0
07	Soil 607	Modelling of soil plant system	2+0
08	Soil 608	Clay Mineralogy	2+1
09	Soil 609	Recent trends in soil microbial biodiversity	2+1
II.	**Minor Courses (6 credits)**		
III.	**Supporting Courses (5 credits)**		
IV.	**Seminar (2 credits)**		
01	Soil 691	Doctoral Seminar	0+1
02	Soil 692	Doctoral Seminar	0+1
V.	**Thesis Research (75 credits)**		
01	Soil 699	Doctoral Research	0+75

* Courses to be compulsorily registered

Soil 601 Recent Trends in Soil Physics (2 + 0)

Aim of the course:

To provide knowledge on modern concepts in soil physics.

Theory

Unit I

Soil-water interactions, soil water potential, free energy and thermodynamic basis of potential concept, chemical potential of soil water and entropy of the system, soil-plant-atmospheric continuum (SPAC). Fundamentals of fluid flow, Poiseuilles law, Laplace's equation, Darcy's law in saturated and unsaturated flows.

Unit II

Development of differential equations in saturated and unsaturated waterflow, capillary conductivity and diffusivity; limitations of Darcy's law; numerical solution for one dimensional waterflow.

Unit III

Theories of horizontal and vertical infiltration under different boundary conditions. Movement of salts in soils, models for miscible-immiscible displacement, diffusion, mass flow and dispersion of solutes and their solutions through differential equations; break-through curves.

Unit IV

Soil air and aeration, mass flow and diffusion processes; thermal properties of soil, heat transfer in soils, differential equation of heat flow, measurement of thermal conductivity of soil; Soil, Plant, Water relations- Plant uptake of soil moisture, Water balance and energy balance in the field; irrigation and water use efficiency.

Unit V

Soil crust and clod formation; structural management of puddled rice soils; soil conditioning-concept, soils conditioners-types, characteristics, working principles, significance in agriculture.

Unit VI

Solar and terrestrial radiation measurement, dissipation and distribution in soil-crop systems; prediction of evapotranspiration using aerodynamic and canopy temperature-based models; canopy temperature and leaf diffusion resistance in relation to plant water deficit; evaluation of soil and plant water status using infra-red thermometer.

Learning Outcome

The students will acquire knowledge on various approaches in soil physics with mathematical background as well as on modern concepts of application of soil physics in relation to soil productivity

Lecture Schedule

Unit I

1. Soil-water interactions- soil water potential- types of soil water-soil water movement-soil water retention curves.
2. Free energy and thermodynamic basis of potential concept- I & II law of the dynamics – chemical potential of soil water and entropy of the system.
3. Soil-plant-atmospheric continuum (SPAC)
4. Fundamentals of fluid flow, Poiseuilles law, Laplace's equation.
5. Darcy's law in saturated and unsaturated flows; Reynolds number

Unit II

6. Development of differential equations in saturated and unsaturated water flow
7. Capillary conductivity and diffusivity; limitations of Darcy's law; numerical solution for one dimensional water flow.
8. Theories of horizontal and vertical infiltration under different boundary condition.
9. Movement of salts in soils – salt distribution-upward/downward movement. Efficiency of water in moving salt.
10. Models for miscible-immiscible displacement-column displacement method-pressure membrane approach-monolithic lysimeters-zero-tension lysimeters-porous cup vacuum lysimeters.

Unit III

11. Infiltration models- Physical models -Green and Ampt - Kostiakov Equation -Horton Equation- Philip Equation.
12. Semi-empirical models- Empirical models-soil conservation service model.
13. Diffusion, mass flow and dispersion of solutes and their solutions through differential equations
14. Dispersion of solutes -Advection- Diffusion- Brownian motion of the molecules- mechanical and hydrodynamic dispersion- Adsorption/desorption
15. Break-through curves- Air-entry suction.
16. Hysteresis

Unit IV

17. Soil air and aeration, mass flow and diffusion processes-Fick's law-composition of soil air- management strategies to improve soil aeration-measurement of soil aeration
18. Importance of soil thermal properties- Correlations between thermal conductivity and soil density or porosity- Effects of ions, salts and other solutes on soil thermal properties
19. Thermal properties of soil, heat transfer in soils, differential equation of heat flow- Fourier law - Measurement of thermal conductivity of soil-

instruments to measure thermal conductivity- guarded hot plate-hot wire-modified hot wire.

20. Plant, Water relations -Plant uptake of soil moisture.
21. Water balance and energy balance in the field; irrigation and water use efficiency.

Unit V

22. Soil crust and clod formation-methods of crusting –physical/ chemical/ biological soil crusting- impact of soil crust – Management of Soil Crust
23. Structural management of puddled rice soils- Effects of puddling on soil properties- Structural management of puddled rice soil
24. Soil conditioning- concept - types- organic / mineral / synthetic soil conditioners.
25. Soils conditioners - characteristics, working principles, significance in agriculture.
26. Solar radiation - beam and diffuse components- Short-wave / long wave radiation
27. Beneficial & Hazardous Effects of Solar Radiation- solar radiation –soil-plant-human health

Unit VI

28. Solar and terrestrial radiation measurement- Actinometer – Pyrheliometer-Pyranometer- Pyranograph- Albedometer, Bolometer –Photometer – Spectroheliograph- Spectrobolometer -Radiometer -working principles.
29. Dissipation and distribution in soil-crop systems. Evapo-transpiration-units-concepts-reference crop evapo-transpiration-energy balance-microclimatological method
30. Prediction of evapo-transpiration using aerodynamic and canopy temperatue- based models- Penman-Monteith equation
31. Canopy temperature and leaf diffusion resistance in relation to plant water deficit- ET & Irrigation.
32. Computation of Water requirement
33. Evaluation of soil and plant water status using infra-red thermometer

Suggested Readings

1. Baver L.D., Gardner W.H. and Gardner W.R. 1972. Soil Physics. John Wiley & Sons.
2. Ghildyal B.P. and Tripathi R.P. 2001. Soil Physics. New Age International.
3. Hanks J.R. and Ashcroft G.L. 1980. Applied Soil Physics. Springer Verlag.
4. Hillel D. 1980. Applications of Soil Physics. Academic Press.
5. Hillel D. 1980. Fundamentals of Soil Physics. Academic Press.
6. Hillel D. 1998. *Environmental Soil Physi*cs. Academic Press.
7. Hillel D. 2003. *Introduction to Environmental Soil Physics*. Academic Press.

8. Hillel D. 2003. Introduction to Environmental Soil Physics. Academic Press.
9. Indian Society of Soil Science. 2002.
10. Fundamentals of Soil Science. ISSS, New Delhi.Kohnke H. 1968. Soil Physics. McGraw Hill.
11. Lal R. and Shukla M.K. 2004. Principles of Soil Physics. Marcel Dekker.
12. Oswal M.C. 1994. Soil Physics. Oxford & IBH.

Suggested websites

1. https://www.elsevier.com
2. https://www.crcpress.com

SOIL 602 Modern Concept in Soil Fertility 2+0

Aim of the course

To provide knowledge of modern concepts of soil fertility and nutrient use in cropproduction.

Theory

Unit I

Nutrient availability-concept and relationships, modern concepts of nutrients availability; soil colloids in relation to nutrient availability; soil amendments and their effect on availability of nutrients, soil solution and plant growth; nutrient response functions and availability indices.

Unit II

Nutrient movement in soils; nutrient absorption by plants; mechanistic approach to nutrient supply and uptake by plants; models for transformation and movement of macro and micronutrients in soils.

Unit III

Chemical equilibria (including solid-solution equilbria) and kinetic studies of nutrients in soils particularly in submerged soils. Modern concepts of fertilizer evaluation, nutrient use efficiency and nutrient budgeting.

Unit IV

Modern concepts in fertilizer application; soil fertility evaluation techniques - concepts an approaches; role of soil tests in fertilizer use and recommendations; various approaches in sit specific nutrient management for precision agriculture - STCR-IPNS approach (Inductive cum targeted yield model), Multiple Regression model, SSNM and Mitscherlich-Bray; sensor base nutrient management; nutrient management in Polyhouse agriculture; nutrient scheduling for fertigation; Role of Decision support system tools in soil fertility management.

Unit V

Monitoring physical, chemical and biological changes in soils; permanent manurial trials and long-term fertilizer experiments; soil productivity under long-term intensive cropping; direct, residual and cumulative effect of fertilizer use. Carbon– a nutrient central to soil fertility; carbon cycle in nature, stocks, pools and fluxes; greenhouse effect and climate change; carbon sequestration vis-à-vis sustenance of soil quality and crop productivity.

Learning outcome

Experience on the knowledge of soil fertility and fertilizers in relation to plant growth and development.

Lecture Schedule

1&2. Nutrient availability – concepts and relationships and Modern concepts of nutrients availability.

3. Soil colloids and nutrient availability, soil amendments and their effect on nutrient availability.

4. Soil solution and models for plant growth.

5. Nutrients response functions and availability indices

6. Nutrient movement in soils

7. Nutrient absorption by plants

8. Mechanistic approach to nutrient supply and uptake by plants

9&12. Models for transformation and movement of macro and micronutrients in soils

13&14. Chemical equilibria (including solid-solution equilibria) and kinetic studies of nutrients in soils particularly in submerged soils

15. Modern concepts of fertilizer evaluation

16. Nutrient use efficiency and nutrient budgeting

17.&18**.** Modern concepts in fertilizer application

19&20. Soil fertility evaluation techniques – concepts and approaches

21. Role of soil tests in fertilizer use and recommendations.

22&24. Various approaches in Site specific nutrient management for precision agriculture - STCR-IPNS approach (Inductive cum targeted yield model), Multiple Regression model, SSNM and Mitscherlich-Bray.

25. Sensor based nutrient management

26. Nutrient management in Polyhouse agriculture and nutrient scheduling for fertigation

27. Role of Decision support system tools in soil fertility management

28. Monitoring physical, chemical and biological changes in soils

29. Permanent Manurial trials and Long-term fertilizer experiments

30. Soil productivity under long-term intensive cropping

31. Direct, residual and cumulative effect of fertilizer use

32. Carbon- carbon cycle, stocks, pools and fluxes

33. Green house effects and climate change

34. Carbon sequestration vis-à-vis sustenance of soil quality and crop productivity

Suggested Readings

1. Barber SA. 1995. Soil Nutrient Bioavailability. 2nd Ed.John Wiley & Sons.
2. Barker V Allen &Pilbeam David J. 2015. Handbook of Plant Nutrition.2nd Ed. CRC /Taylor & Francis.
3. Brady NC & Weil RR. 2016. The Nature and Properties of Soils. 15th Ed.Pearson Educ

4. Epstein E. 2004. Mineral Nutrition of Plants - Principles and Perspectives.2nd Ed. International Potash Institute, Switzerland.
5. Goswami, N., Rattan, R.K., Dev, G., Narayanasamy, G., Das, D.K., Sanyal, S.K., Pal, D.K. and Rao, D.L.N. (Eds.), 2012. Fundamentals of Soil Science. 2nd Edn.(revised), Indian Society of Soil Science, New Delhi.
6. Havlin, JL., Tisdale, SL., Nelson, WL & Beaton JD. 2017. Soil Fertility and Fertilizers – An Introduction to Nutrient Management 8th Edn. Pearson publn.
7. Kabata- Pendias Alina 2010. Trace Elements in Soils and Plants.4th Ed.CRC /Taylor &Francis.
8. Kannaiyan S, Kumar K and Govindarajan K. 2004. *Biofertilizers Technolo*gy. Scientific Publ.
9. Klaus Lorenz & Rattan Lal. 2018. Carbon Sequestration in Agricultural Ecosystems. Springer Science + Business Media, Switzerland.
10. Lal, R. 2016. Soil health and carbon management. Food Energy Secur. 5(4): 212–222. doi: 10.1002/fes3.96.
11. Lal, R. 2020. Carbon-Centric Integrated Nutrient Management: A Solution for Enhancing Farm Prod00uctivity and Carbon Sequestration in India. Indian J. Fertil. 16(4): 300–312.
12. Lal, R. 2020. Long-term Agricultural Experiments and Global Issues. Indian J. Fertil.16(12): 1220–1227.
13. Mortvedt JJ, Shuman LM, Cox FR & Welch RM. (Eds.). 1991. Micronutrients in Agriculture. 2nd Edn. Soil Science Society of America, Madison.
14. Prasad R & Power JF. 1997. Soil Fertility Management for Sustainable Agriculture, CRC Press.
15. Russell, E. W. 2007. Soil Conditions and Plant Growth. 8th Edn., Biotech Books, New Delhi.
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Suggested Websites

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5. http://soils.wisc.edu/extension/materials/Diagnosing_Nutrient_Needs.pdf UNIVER
6. https://nrcca.cals.cornell.edu/
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9. http://base.dnsgb.com.ua/files/book/Agriculture/Soil/Trace-Elements-in-Soils-and-Plants.pdf
10. https://marwanbaloch.files.wordpress.com/2015/01/soil-conditions-and-plant-growth.pdf

Soil 603 Physical Chemistry of Soil (2 + 0)

Aim of the course

To impart knowledge about modern concepts of physical chemistry of soils and clays, with emphasis on understanding the processes involved with practical significance.

Theory

Unit I

Soil physical chemistry - significance – soil colloids- properties- Colloidal chemistry- Clay minerals- Formation- characteristics, surface charge characteristics- structural chemistry - empirical and diffuse double layer theories (DDL)-structure and properties- relationships among different selectivity coefficients- factors affecting DDL- Merits and Demerits.

Unit II

Organic colloids- humic and non humic substances - properties and genesis- clay humus complex- nature and properties of humus complexes – mechanisms of clay humus complex formation - forces and bonding involved - clay -organic interactions- significance – Climate change effects on mineralogy and surface properties of variable charges.

Unit III

Cationic and anionic exchange and their models, molecular interaction. Predictive approaches for cation exchange equilibrium - Empirical equations and approaches - Mass action equation and kinetic equation- Adsorption equations. Equations derived from statistical models-Factors affecting ion exchange reactions in soils- Hysteresis - clay-water-nutrient interaction.

Unit IV

Adsorption/desorption isotherms-Langmuir adsorption isotherm, Freundlich adsorption isotherm, normalized exchange isotherm, BET equation; selective and non-selective adsorption of ions on in organic surfaces and organic surfaces of soil materials (citation of utility in agricultural system). Thermodynamics of nutrient transformations in soils. Q/I relationship

Unit V

Fixation reactions in soil colloids - fixation of nutrients at structural exchange sites - Common solubility equilibria-carbonates, iron oxide and hydroxides, aluminum silicate, aluminum phosphate; electrochemical properties of clays (citation of examples from agricultural use). Redox chemistry of soils

Learning outcome

Students will gain knowledge on soil colloids, its physical chemistry, adsorption reactions and chemical processes involved in ion exchange to relate

its role in nutrient fixation, release and availability as well as on modern concepts of application of soil physics in relation to soil productivity.

Lecture Schedule

Unit I

1. Soil physical chemistry- definition, significance, Soil colloids and their properties
2. Colloidal chemistry: Inorganic components of soils -basics of silicates minerals
3. Chemistry of clay minerals-surface charge characteristics-structural and surface chemistry - I
4. Chemistry of clay minerals-surface charge characteristics-structural and surface chemistry-II
5. Empirical and diffuse double layer theories **(**DDL)-structure and properties.
6. Selectivity coefficients -factors affecting DDL-Merits and Demerits.

Unit II

7. Organic Colloids- humic substances - properties and genesis
8. Organic Colloids- non-humic substances - properties and genesis
9. Clay humus complex- nature and properties
10. Mechanisms of clay humus complex formation
11. Clay -organic interaction - forces and bonding involved- its significance.
12. Climate change on mineralogy and surface properties of variable charges

Unit III

13. Ion exchange definitions and rules-characteristics and types of reactions molecular interaction
14. Theories of ion exchange cation exchange equilibria, Empirical equations, and approaches.
15. Theories of cation exchange based on mass action law equation and kinetic equations.
16. Anionic exchange -Models, methodologies, and kinetics of ion exchange
17. Significance of Ion exchange reactions in plant nutrition
18. Adsorption equations- statistical models.

Unit IV

19&20. Factors affecting ion exchange reactions in soils- Hysteresis - clay-water-nutrient interaction.

21. Adsorption/desorption - isotherms models -Langmuir, Freundlich and normalized exchange isotherm, BET equation.

22. Selective and non-selective adsorption of ions on inorganic and organic surfaces of soil materials.

23. Thermodynamics of nutrient transformations in soils- Major nutrients

24. Thermodynamics of nutrient transformations in soils- Secondary nutrients

25. Thermodynamics of nutrient transformations in soils- Micronutrients

26. Quantity /Intensity relationships

Unit V

27. Fixation reactions in soil colloids

28. Fixation of nutrients at structural exchange sites.

29. Common solubility equilibria-Ratio law- carbonates, iron oxide and hydroxides

30. Common solubility equilibria- aluminum silicate, aluminum phosphate

31. Electrochemical properties of clays - factors affecting electrochemical properties

32. Redox chemistry of soils-Oxidation-Reduction reactions,

33. Significance & measurement and use of redox potentials

34. Chemistry of submerged soil.

Suggested Readings

1. Bear RE. 1964. *Chemistry of Soil.* Oxford & IBH.
2. Bolt GH and Bruggenwert MGM. 1978. *Soil Chemistry*. Elsevier.
3. Fried M and Broeshart H. 1967. *Soil Plant System in Relation to Inorganic Nutrition.* Academic Press.
4. Greenland DJ and Hayes MHB. 1981. *Chemistry of Soil Processes*. John Wiley & Sons.
5. Greenland DJ and Hayes MHB. 1978. *Chemistry of Soil Constituents*. John Wiley & Sons.
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7. McBride MB. 1994. *Environmental Chemistry of Soils.* Oxford University Press.
8. Sparks DL. 1999. *Soil Physical Chemistry*. 2nd Ed. CRC Press.
9. Sposito G. 1981. *The Thermodynamics of Soil Solutions*. Oxford University Press.
10. Sposito G. 1984. *The Surface Chemistry of Soils*. Oxford University Press.
11. Sposito G. 1989. *The Chemistry of Soils*. Oxford University Press.
12. Stevenson FJ. 1994. *Humus Chemistry*. 2nd Ed. John Wiley.
13. van Olphan H. 1977. *Introduction to Clay Colloid Chemistry*. John Wiley & Sons.

Suggested websites

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2. https://www.vaderstad.com/en/know-how/basic-agronomy/let-nature-do-thework/ soil-water
3. http://lawr.ucdavis.edu

4. https://apps.dtic.mil
5. http://digitool.library.mcgill.ca/
6. http://www.cfms-sols.org.
7. http://www.soilmanagementindia.com

Soil 604 Soil Genesis and Micromorphology 2+0

Aim of the course

To impart knowledge about the pedogenic processes in soils and to acquaint withthe micro-pedological study of soil profile.

Theory

Unit I

Pedogenic evolution of Soil - Fundamental Concept of soil genesis - Soils – Concepts and definitions - Soil composition – Rock forming minerals, Formation, characterization and classification.

Unit II

Rocks – Formation, nature and classification - Weathering of rocks and minerals and soil formation – Soil forming factors and processes in pedogenesis; Stability and weathering sequences of minerals.

Unit III

Soil Profile – Master and transition Horizons – Subordinate designations - Soil Orders - Utility of soil analysis in pedological investigation of soil - Assessment of soil profile development by morphological, mineralogical and chemical analysis.

Unit IV

Micro pedology – Its Importance in Soil Formation – Concepts of structure and fabric in Micropedology.

Unit V

Micro-pedological features of soils – Their structure, fabric analysis - Role in genesis and classification

Learning outcome

Experience on the knowledge of soil micro pedology and soil taxonomy on researchfor solving field problems.

Lecture Schedule

1. Pedogenic evolution of Soil - Fundamental Concept of soil genesis, soil Individual and pedology - Methods of soil genesis study - The role of soil genesis and classification.
2. Soil versus Regolith - Morphology and Composition of Soils
3. Evolution of Earth – Interior of Earth - Composition of Earth's Crust – Rocks in the earth's Crust
4. Rock Forming Minerals –Their Formation, Characterization and Classification
5. Rocks – Their Formation, Characterization and Classification
6. Soil Materials - Weathering of Rocks and Minerals – Weathering of Silicates

7. Soil Formation – Conceptualizing the Environment of Soil Formation – Soil Forming Factors -Passive and Active Soil Forming Factors
8. Processes in Pedogenesis (Fundamental & Specific)
9. Weathering – Stability & Weathering Sequences of Mineral
10. Early and Modern Soil Classification Systems - World Reference Base (WRB)
11. U.S. Soil Taxonomy – A comprehensive System
12. Soil profile – Master horizons – Subordinate distinctions within Master horizons
13. Diagnostic Soil Horizons – Epipedons and Endopedons
14. Soil Orders – Alfisols: High Base Status Soils with Finer-textured Subsoil Horizons; Andisols: Soils with Andic Soil Properties ; Aridisols: Soils of Dry Regions; Entisols: Recently Formed Soils
15. Soil Orders - Gelisols: Very Cold Soils ; Histosols: Organic Soils ; Inceptisols: Embryonic Soils with Few Diagnostic Features ; Mollisols: Grassland Soils of Steppes and Prairies **;** Oxisols: Low Activity Soils
16. Soil Orders – Spodosols: Soils with Subsoil Accumulations of Humus and Sesquioxides ; Ultisols: Low Base Status Soils with Finer-textured Subsoil Horizons ; Vertisols: Shrinking and Swelling Dark Clay Soils
17. Spatial Arrangement of Soils: Soil scapes and Map Units
18. Spectral Characterization of the Soils
19. Soil Morphological Features – Identification criteria and application
20. Assessment of Soil Profile development by Morphological and Mineralogical analysis
21. Assessment of Soil Profile development by Chemical Analysis
22. Micro pedology – Introduction and its importance in soil formation – Evolution of Micropedology
23. Approaches of soil thin section description and Applications of soil thin section in Soil genesis
24. Basic Concepts of structure and fabric in Micro pedology – General Descriptive criteria
25. Micro structure – Description – Types
26. Basic mineral components and Soil thin section
27. Basic organic components and soil thin section
28. Groundmass of soil thin section
29. Micro pedo features - 1. General 2. Textural pedo features 3. Depletion pedo features
30. Micro pedo 4. Crystalline pedo features 5. Amorphous and Cryptocrystalline pedo features
31. Micro pedo features - 6. Fabric pedo features 7. Excrement pedofeatures
32. Micro – pedological features and their role Soil Genesis and Classification
33. Soil thin section – Description and morphological classification of pedofeatures as related to their fabric

Suggested Readings

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and classification of soils in Abu Dhabi coastal area in relation to arid and semi-arid conditions using USDA and FAO soil classification systems. Arid Land Research and Management, 21(3), 245-271.

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3. Brewer R. 1976. Fabric and Mineral Analysis of Soils. John Wiley & Sons.

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5. Buol, S.W., R. J. Southard, R. C. Graham and P. A. Mcdaniel .2011. Soil Genesis and Classification. Sixth Edition. A John Wiley & Sons, Ltd.,Publication. Sixth edition. ISBN-13:978-0-8138-0769-0/2011.

6. Dilip Kumar Das. 2015. Introductory soil science. Kalyani publishers. pp 1-879.

7. Douglas, L.A. 1990. Soil Micromorphology - A Basic and Applied Science. Volume 19.1st Edition, Elsevier Science, eBook ISBN: 9780080869872

8. Galbraith, J. M. (2018). Human-altered and human-transported (HAHT) soils in the US soil classification system. Soil Science and Plant Nutrition, 64(2), 190-199

9. Hossner L.R., Yatsu E., Young I.M., Warland J., Stoops G. (2008) Micromorphology. In: Chesworth W. (eds) Encyclopedia of Soil Science. Encyclopedia of Earth Sciences Series. Springer, Dordrecht.

10. Jamagne, M., & King, D. (2002). 13 CHAPTER The Current French Approach to a Soilscapes Typology. Soil Classification: A Global Desk Reference, 157.), 163-172.

11. Karuma, A. N., C. K. K, Gachene., B.M, Msanya., P. W. Mtakwa., N. Amuri and P.T. Gicheru. 2015. Soil Morphology, Physico - Chemical Properties and Classification of Typical Soils of Mwala District, Kenya International Journal of Plant & Soil Science 4(2). Pp : 156-170.

12. Kubiena, Walter L. "Micropedology." Soil Science 47, no. 2 (1939): 163

13. Kühn,P., J. Aguilar., R. Miedema, and M. Bronnikova. 2018. Textural Pedofeatures and Related Horizons. Interpretation of Micromorphological Features of Soils and Regoliths (Second Edition) Copyright © 2018 Elsevier B.V. All rights reserved. Pp: 377-423.

14. Mary C. B. Fanning, Delvin S. Fanning. 2013. Soil : Morphology, Genesis And Classification. 1st Edition. Publisher: Wiley ; ISBN: 9788126544493, 812654449X

15. Mendonça, B. A. F. D., Schaefer, C. E. G. R., Fernandes-Filho, E. I., Simas, F. N. B., & Amaral, E. F. D. (2020). Genesis and micropedology of soils at Serra do Divisor and Moa river floodplain, northwestern Acre, Brazilian Amazonia. RevistaBrasileira de Ciência do Solo, 44.

16. Murphy C.P., A. Mckeague , L.M. Bresson , P. Bullock, J. Kooistra, and G. Stoops. Description of soil thin sections: an international Comparison. Geoderma, 35 (1985) 15- 37

17. Nsor, M. E, and I. J. Ibanga. 2008.Morphological Characteristics And Classification Of Soils Derived From Diverse Parent Materials In Central Cross River State,Nigeria.Global Journal Of Pure And Applied Sciences.14(3). Pp : 271 – 277.

18. Schmidt, K., Behrens, T., Friedrich, K., &Scholten, T. (2010). A method to generate soilscapes from soil maps. Journal of Plant Nutrition and Soil Science, 173(2).

19. Sehgal, J. 2005. A Text Book of Pedology – Concepts and Applications. Kalyani Publishers. ISBN 81 272 2677 7 Reprinted in 2020.

20. Soil Survey Staff (2003) Soil Taxonomy, Agricultural Handbook, Title 436, Third Edition, US Department of Agriculture, Washington DC, USA, 869 Pp

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25. Stoops, G. and Jongerius, A., 1975. Proposal for a micromorphological classification of soil materials, I. A classification of the related distributions of fine and coarse particles. Geoderma, 13: 189—1.

26. Stoops, G., Marcelino, V., & Mees, F. (Eds.). 2018. Interpretation of micromorphological features of soils and regoliths. Elsevier.

27. Stoops, G., & Schaefer, C. E. 2018. Pedoplasmation: formation of soil material. In Interpretation of micromorphological features of soils and regoliths (pp. 59-71). Elsevier

28. Terribile F and FitzPatrick E.A. The application of multilayer digital image processing techniques to the description of soil thin sections. 1992 .Geoderma. 55 :159-174.

29. Van Quang Pham.. Soil Formation and Soil Moisture Dynamics in Agriculture Fields (English, Paperback, Van Quang Pham) Publisher: VDM Verlag ; ISBN: 9783639230314, 3639230310

30. Verrecchia, E. P., L. Trombin. 2021. A Visual Atlas for Soil Micromorphologists. **https://doi.org/10.1007/978-3-030-67806-7_3**

31. Watteau, F., Huot, H., Séré, G., Begin, J. C., Rees, F., Schwartz, C., & Morel, J. L. (2018). Micropedology to reveal pedogenetic processes in Technosols. Spanish Journal of Soil Science: SJSS, 8(2), 148-163.

32. World Reference Base for Soil Resources 2014- International soil classification system for naming soils and creating legends for soil map. Food and Agriculture Organization of The United Nations, Rome, 2014

Suggested Websites

1. https://www.cambridge.org/core/...soils.../B2F7D71F19E2A6D7A23F98FC04734A28 References - Applied Soils and Micromorphology in Archaeology
2. **https://passel2.unl.edu/view/lesson/2eafec8dd762/2**
3. http://www.edafologia.net/english/index.htm
4. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054254
5. **https://doi.org/10.1007/978-1-4020-3995-9_355**
6. https://www.researchgate.net/.../260788548_Experimental_micropedology-_a_techniqu.Experimental micropedology- a technique for investigating soil
7. http://iuss.boku.ac.at/index.php?article _id=649 ... soil science, especially genesis classification and micropedology.
8. https://iuss.boku.ac.at/files/00000101.pdf of the International Union of Soil Sciences 2002/1 The qualitative and quantitative assessment of soil genesis often needs insight

SOIL 605 BIOCHEMISTRY OF SOIL ORGANIC MATTER (2+0)

Aim of the Course

To impart knowledge related to chemistry and reactions of organic substances and their significance in soils

THEORY

UNIT I

Organic matter pools in soil; composition and distribution of organic matter in soil and its functions; environmental significance of humic substances; decomposition of organic residues in soil in relation to organic matter pools.

UNIT II

Biochemistry of the humus formation; different pathways for humus synthesis in soil; soil carbohydrates and lipids.

UNIT III

Nutrient transformation – N, P, S; trace metal interaction with humic substances, significance of chelation reactions in soils.

UNIT IV

Reactive functional groups of humic substances, adsorption of organic compounds by clay and role of organic substances in pedogenic soil aggregation processes; clay-organic matter complexes. Humus - pesticide interactions in soil

UNIT V

Mechanisms- Current thinking in the maintenance of soil organic matter, compost, Vermi technology. Carbon sequestration-methods and significance

Learning Outcome

Experience on the knowledge of soil biochemistry on research for solving field problems

Lecture Schedule

Unit I

1. Soil organic matter-Introduction
2. Organic matter pools in soil
3. Composition and distribution of organic matter in soil

4. Functions of organic matter in soil

5. Humic substances: structure and concept

6. Environmental significance of humic substances

7. Decomposition of organic residues in soil in relation to organic matter pools.

Unit II

8. Methods of assessing the age of humic substances

9. Biochemistry of the humus formation

10. Different pathways for humus synthesis in soil – lignin theory

11. Humus synthesis- Polyphenol theory, sugar- amine theory

12. Soil carbohydrates

13. Soil lipids

Unit III

14. Nutrient transformation of N and interaction with humic substances

15. Nutrient transformation of P and interaction with humic substances

16. Nutrient transformation of S and interaction with humic substances

17.&18. Significance of chelation reactions in soils

Unit IV

19. Reactive functional groups of humic substances

20. Interaction of trace elements with humic substances

21. Adsorption of organic compounds by clay

22. Role of organic substances in pedogenic soil aggregation processes

23. Clay-organic matter complexes

24. Characterization of clay humus complex

25. Humus - pesticide interactions in soil and their mechanisms

26.Clay pesticide complex

Unit V

27. Recycling of soil organic matter and criteria for recycling of organic matter

28. Crop residue management

29. Importance of compost in maintenance of soil organic matter

30. Composting techniques

31. Vermitechnology

32. Carbon Sequestration-Environmental significance

33. Soil carbon sequestration methods

34. Impact of agriculture on Soil carbon sequestration

Suggested Readings

1. Beck A.J., Jones K.C., Hayes M.H.B and Mingelgrin U. 1993. Organic Substances in Soil and Water: Natural Constituents and their 104 Influences on Contaminant Behavior. Royal Society of Chemistry, London.

2. Gieseking JE. 1975. Soil Components. Vol. 1. Organic Components. Springer-Verlag.

3. Kristiansen P, Taji A and Reganold J. 2006. Organic Agriculture: A Global Perspective. CSIRO Publ.270

4. Magdoff. F and Weil RR 2004. Soil Organic Matter in Sustainable Agriculture. CRC Press.

5. Mercky R and Mulongoy K. 1991. Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture. John Wiley & Sons.

6. Paul EA. 1996. Soil Microbiology and Biochemistry. Academic Press.

7. Stevenson FJ. 1994. Humus Chemistry – Genesis, Composition and Reactions. John Wiley & Sons.

8. Stotzky and Jean-Marc Bollag (ed.,) 1992 Soil Biochemistry Marcel Decker. Inc. New York 9. Vaughan, D and R. E. Malcolm, (Eds)1985 Soil Organic Matter and Biological Activity Martinus Nijhoff, Dordrecht, The Netherlands

10. Kononova M.M 2013 Soil Organic Matter: Its Nature, Its Role in Soil Formation and in Soil Fertility Pergamon press Publishers, Oxford

Suggested Websites

1.https://ecaf.org/wp-content/uploads/2021/02/Soil_Organic_Matter-Brian_Murphy.pdf

2.https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/soil-organicmatter

3. https://www.frontiersin.org/articles/10.3389/feart.2021.590103/full

4. https://www.nature.com/articles/nature16069

5. http://eagri.org/eagri50/SSAC121/lec17.pdf

Soil 606 Soil Resource Management 3+0

Aim of the course

To impart the students basic holistic knowledge on soil resource and latest developments in its sustainable use.

Theory

Unit I

Relevance of soil management to sustainable agriculture; soil as a natural resource for biomass production, filtering, buffering, transportation of solutes, gene reserves, and geogenic source of raw materials; soil as a source and sink of greenhouse gases. Concept of sustainable land management (SLM); spatial variability of soils; soil quality and food security; soil quality indices, conservation agriculture in relation to soil quality; soil resilience and resistance

Unit II

Types, factors and causes of land degradation and desertification; GLASOD classification; application of GIS and remote sensing in monitoring, diagnosis and mapping land degradation. History, distribution, identification and description of soil erosion problems in India; forms of soil erosion; impact of soil erosion-on-site and off-site effects; strategies for erosion control and conservation; soil conservation in hilly, arid, semiarid, coastal and diara lands. Management of forest, peat and muck soils.

Unit III

Soil conservation planning; land capability classification; soil conservation in special problem areas such as hilly, arid and semi-arid regions, waterlogged and wetlands. Land restoration and conservation techniques–erosion control, reclamation of salt affected soils; mine land reclamation, afforestation, organic products, soil fauna and biodegradation.

Unit IV

Watershed management-concept, objectives and approach; water harvesting and recycling; flood control in watershed management; socio-economic aspects of watershed management; case studies in respect to monitoring and evaluation of watersheds.

Unit V

Agro-ecological regions of India; potentials and constraints of soils of different regions; land evaluation and rationalizing land use, decision support system with relation to land management; national and international soil policy considerations.

Learning outcome

Experience on the knowledge of soil resources on research for solving field problems.

Lecture Schedule

1. Soil management and sustainable agriculture
2. Soil as a natural resource for biomass production
3. Soil and natural filtering
4. Soil buffering
5. Transportation of solutes, gene reserves
6. Geogenic source of raw materials
7. Soil as a source and sink of greenhouse gases
8. Concept of Sustainable Land Management
9. Spatial variability of soils
10. Soil quality and food security
11. Soil quality indices
12. Conservation agriculture in relation to soil quality
13. Conservation agriculture in relation to soil resilience
14. Conservation agriculture in relation to soil resistance
15. Types and factors of land degradation and desertification
16. Causes of land degradation and desertification
17. GLASOD classification
18. Application of GIS and remote sensing in crop monitoring
19. Application of GIS and remote sensing in soil monitoring
20. Application of GIS and remote sensing in crop loss
21. Diagnosis and mapping land degradation
22. Soil erosion and forms
23. History, distribution, identification and description of soil erosion problems in India
24. Impact of soil erosion-on site and off-site effects
25. Strategies for erosion control and conservation
26. Soil conservation in hilly, arid, semi-arid, coastal and diara lands
27. Management of forest, peat and muck soils
28. Soil conservation planning
29. Land capability classification
30. Soil conservation in special problem areas such ashilly, arid and semi-arid regions
31. Soil conservation in special problem areas such as waterlogged and wetlands
32. Land restoration and conservation techniques– erosion control

33. Reclamation of salt affected soils
34. Mine land reclamation through afforestation, organic products, soil fauna and biodegradation
35. Watershed management-concept, objectives and approach
36. Water harvesting and recycling
37. Flood control in watershed management
38. Socio-economic aspects of watershed management
39. Case study 1 : Monitoring and evaluation of watersheds
40. Case study 2 : Monitoring and evaluation of watersheds
41. Agro-ecological regions of India
42. Potentials and constraints of soils of Northern India
43. Potentials and constraints of soils of Southern India
44. Potentials and constraints of soils of Eastern India
45. Potentials and constraints of soils of Western India
46. Potentials and constraints of soils of Central India
47. Land evaluation and rationalizing land use
48. Decision support system with relation to land management
49. National soil policy considerations
50. International soil policy considerations

Suggested Readings

1. Singh, R.V. 2003. Watershed Planning and Management. Second Edition. Yash Publishing House, Bikaner.
2. Murty, V .V. N. 1998. Land and Water Management Engineering. 2nd Ed. Kalyani Publishers Ludhiana
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6. Sadanandan Nambiar EK & Grown AG. (Eds.). 1997. Management of Soil, Nutrients and Water in Tropical Plantation Forests. ACIAR, CSIR and CIFOR, Australia.103
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12. Burrough A and McDonnell RK. 1998.*Principles of Geographical Information System*. Oxford University Press.
13. Abrol IP and Dhruvanarayana VV. 1990. *Technology for Wasteland Development*. ICAR, New Delhi.
14. Faroq M and Siddique K. (Ed.). 2015. *Conservation Agriculture*, Springer Nature, Chennai, India.
15. ISSS. 1994. *Management of Land and Water Resources for Sustainable Agriculture and Environment*. Diamond Jubilee Symposium Publication, Indian Society of Soil Science, New Delhi.
16. Sehgal J. 2014. *A Text Book of Pedology Concepts and Application*. Kalyani publishers, New Delhi.

Suggested Websites

1. www.iifm.org
2. www.pfmt.org
3. www.forestprotection.com

Soil 607 Modelling of Soil Plant System 2+0

Aim of the course

To train the students in concepts, methodology, technology and use of systems simulation in soil and crop studies

Theory

Unit I

Introduction, terms and definitions; classification of models; Taylor series; numerical methods of differentiation and integration. Application of modelling; Potentials and limitations of simulation modeling: Determinacy and randomness, Error and linearity.

Unit II

High level computer language: FORTRAN-its commands and usage; testing and evaluation of model- Database and model development, model validation, on farm use of crop models.

Unit III

Description of spatially homogeneous models; K transformation model; nitrogen and phosphorus dynamics in soil. Application of GIS in spatial analysis, models in soil formation, soil biological process, soil organic matter dynamics

Unit IV

Spatially heterogeneous models; equation of continuity; Simulation of water flow through soil; Explicit and Explicit-Implicit method; simulation of solute movement through soil with variable moisture flux by explicit-implicit method.

Unit V

Nutrient uptake model: Integration of nutrient movement in soil (mass flow and diffusion) and uptake by plants (Michaelis-Menten kinetics); Nutrient uptake model: Solubility and free ion activity model.

Learning outcome

Experience on soil modelling concept for forecasting productivity

Lecture Schedule

1. Introduction- terms and definitions- Basic concepts of Modelling & Simulation- Object- Base model
2. System- Experimental Frame- Frame Input Variables- Frame Output Variables- Lumped Model-system state variables
3. Classification of models- Discrete-Event Simulation Model- Stochastic vs. Deterministic Systems- Static vs. Dynamic Simulation- Discrete vs. Continuous models
4. Models for simulation of soil behavior - Hookes model- Mohr-Coulumb Model, Cam clay Model- Hyperelastic Model- Hypoelastic Model- Plaxis

hardening soil Model

5. Empirical models- mechanistic models- Taylor series-Taylor series expansion-Taylor polynomial-Examples of Taylor series
6. Numerical methods of differentiation and integration- Application of modelling- Potentials and limitations of simulation modelling: Determinacy and randomness- Error and linearity
7. High level computer language- List of high level computer language-FORTRAN-Features-its commands and usage
8. Testing and evaluation of model- Using analytical solutions-Using field data-classification evaluation-Regression evaluation
9. Modelling process -Database and model development
10. Model validation- methods- Split Sample Validation - Cross Validation – Bootstrapping Validation – Model validation matrics-On farm use of crop models
11. Description of spatially homogeneous models-logical structure-Examples
12. K transformation model; nitrogen and phosphorus dynamics in soil
13. Application of GIS in spatial analysis- models in soil formation
14. Models in Soil biological process- models in soil organic matter dynamics
15. Spatially heterogeneous models- equation of continuity
16. Simulation of water flow through soil
17. Explicit and Explicit-Implicit method
18. Simulation of solute movement through soil with variable moisture flux by explicit-implicit method
19. Nutrient uptake model : Mechanistic simulation models
20. Integration of nutrient movement in soil (mass flow and diffusion)
21. Nutrient uptake by plants (Michaelis-Menten kinetics)
22. Nutrient uptake model: Solubility and free ion activity model
23. Commonly used models in soil research-soil plant atmosphere system model (SPASMO)
24. Commonly used models in soil research: soil carbon dynamics – CENTURY-ROTH-C
25. Commonly used models in soil research: GHG emission – MERES,DNDC
26. Commonly used models in soil research: NPK (WOFOST), N pollution (APEX)
27. Commonly used models in soil research: Nutrient budget (NUTMON)
28. Commonly used models in crop research: DSSAT
29. Commonly used models in crop research: CERES
30. Commonly used models in crop research: STICS

31. Commonly used models in crop research: CROPSYST
32. Commonly used models in crop research: root growth models
33. Discussion on database requirement and output of Commonly used models in soil / crop research

Suggested Readings

1. Theory and Principles of Simulation Modeling in Soil-Plant System. S.C. Datta, Capital Publishing Company, New Delhi, 2008
2. Modeling Carbon and Nitrogen Dynamics for Soil Management. 2001, Edited by M.J. Shaffer, L. Ma and S. Hansen, Lewis Publishers, Boca Raton, Fl
3. Mathematical Models in Agriculture - A Quantitative approach to problems in agriculture and related science. J. Frame and J.H.M Thornley, Butterworth andCo. Ltd., 1984.
4. Modeling Plant and Soil System. J. Hanks and J.T. Richie (Eds.) Agronomy Bulletin No.31, ASA, SSSA Madison, Wisconsin, USA
5. Simulation of Accumulation and Leaching in Soils. M.lFrissel, and P. Reinger Oxford and IBM Pub.Co. New Delhi 1974
6. Regression Methods – A tool for data Analysis, RJ. Freud and P.D. Minton, Marcel Dekker Inc., New York
7. Schaum's Outline Series- Theory and Problems of programming with Fortran. S. Lipschutz and A. Poe., McGraw-Hill Book Co., Singapore.
8. Simulation of ecophysiologica1 processes of growth in several annual crops. F.W.T Penning de Vries, D.M. Jansen, H.F.M. Ten Berge and A, Baker, PUDOC, Wageningen 1989

Suggested Websites

1. www.nrcs.usda.gov
2. www.isric.org
3. www.mdpi.com
4. www.soilmapper.org
5. www.bigdata.cgiar.org
6. www.wamis.org
7. www.macsur.eu
8. https://fortran-lang.org/
9. https://gcc.gnu.org/fortran/

Soil 608 Clay Mineralogy 2+1

Aim of the course

To impart knowledge on characterization, distribution and identification of clay minerals.

Theory

Unit I

Definition and concepts of clays and clay minerals, Fundamentals of crystallography – unit cell, external characteristics of crystals, crystallographic notations, crystal systems- X-ray crystallography- Bragg's law- Pauling's rule- Structures and classification of silicate minerals, basics of phyllosilicates- laws governing structural characteristics of phyllosilicates.

Unit II

Goldschmitdt's laws-Laws I and Law II, Classification of Phyllosilicates- Kaolonite group of minerals, Dioctahedral kaolins and Trioctahedral kaolins- Smectites; properties of smectites, Reference models of structure, principal types based on Hofmann-Marshal-Hendricks (H-M-H) models, occurrence of smectites, transformation and formation in soils

Unit III

Micas: occurrence and origin in soils, polytypes of micas, structure and formation of muscovites and illite- Vermicullites: structure, occurrence in soils, formation, relation between vermiculites and montmorillonite- Chlorite: occurrence and structure of chlorites, "swelling chlorites", formation of chlorite. Methods of Identification of clay minerals

Unit I V

Non-crystalline clays (amorphous materials), subgroups and chemical composition, morphology and structure, physico-chemical properties, influence of non-crystalline clays on soil properties- Interstratified clay minerals, occurrence and formation in soils, regularly interstratified and partially random interstratified minerals- Zeolites: properties and applications

Unit V

Genesis and transformation of clay minerals, Generalized conditions for formation and persistence of common clay-size minerals in soils. Surface chemistry of clay minerals, clay-organic complexes, nanoclay mineralogy. Clay minerals in different soil orders, role of clay minerals in soil fertility management.

Practical

Separation of clay for mineralogical study; X-ray diffraction analysis of clay; Selective dissolution of clay minerals-IR, DTA and SEM of clay minerals - Identification and quantification of clay minerals -Determination of surface charge of clay minerals -Potentiometric titration of clay minerals.

Learning outcome

Experience on soil clays and utility in soil research

Lecture Schedule

1. Definition and concepts of clays and clay minerals
2. Fundamentals of crystallography – unit cell, external characteristics of crystals
3. Crystallographic notations, crystal systems
4. X-ray crystallography, Bragg's law, Pauling's rule
5. Structures and classification of silicate minerals
6. Basics of phyllosilicates
7. Laws governing structural characteristics of phyllosilicates
8. Goldschmitdt's laws – Law I and Law II
9. Classification of Phyllosilicates
10. Kaolonite group of minerals, Dioctahedral kaolins and Trioctahedral kaolins
11. Smectites; properties of smectites
12. Reference models of structure- principal types based on Hofmann-Marshal-Hendricks (H-M-H) models
13. Occurrence of smectites, transformation and formation in soils
14. Micas: occurrence and origin in soils, polytypes of micas
15. Structure and formation of muscovites and illite
16. Vermicullites: structure, occurrence in soils, formation
17. Relation between vermiculites and montmorillonite
18. Chlorite: occurrence and structure of chlorites, "swelling chlorites", formation of chlorite
19. Methods of Identification of clay minerals: Analytical methods
20. Methods of Identification of clay minerals: Instrumental methods
21. Non-crystalline clays (amorphous materials): subgroups and chemical composition
22. Non-crystalline clays : morphology and structure
23. Non-crystalline clays : physico-chemical properties
24. Influence of non-crystalline clays on soil properties
25. Interstratified clay minerals, occurrence and formation in soils
26. Regularly interstratified and partially random interstratified minerals
27. Zeolites : properties and applications
28. Genesis and transformation of clay minerals
29. Generalized conditions for formation and persistence of common clay-size

minerals in soils

30. Surface chemistry of clay minerals
31. Clay-organic complexes, nanoclay mineralogy
32. Clay minerals in different soil orders
33. Role of clay minerals in soil fertility management

Practical Schedule

1. Sample preparation and removal of soluble salts, carbonates, organic matter and iron and aluminium oxides
2. Dispersion and fraction of sand, silt, clay and fine clay
3. Cation saturation and preservation of clay
4. X-ray diffraction technique - sample preparation
5. Thermal and infra-red spectroscope - sample preparation
6. Scanning and transmission microscopes - sample preparation
7. Estimation of vermiculite and montmorillonite by CEC hysteresis
8. Estimation of non-crystalline iron and aluminium oxides by citrate bicarbonate, dithionite dissolution
9. Estimation of amorphous minerals by acidic ammonium oxalate dissolution
10. Estimation of quartz, feldspar and mica by sodium pyrophosphate selective dissolution
11. Estimation of kaolinite and chlorite by heat destruction
12. Determination of clay CEC
13. Determination of clay surface area by EGMA technique
14. Determination of heat of wetting of clay minerals
15. Sample analysis by X-ray diffraction, DTA and Scanning electron microscopy
16. nterpretation of X- ray diffratogram and quantification of clay minerals
17. **Final practical examination**

Suggested Readings

1. Rutley's Elements of Mineralogy H.H. Read
2. Clay Mineralogy Ralph E. Grim
3. Soil Component Vol. 2. Inorganic Components John E. Gieseking (Ed).

Suggested Websites

1. www.worldcat.org
2. www.web.viu.ca
3. www.claysandminerals.com

SOIL 609 Recent Trends in Soil Microbial Bio-Diversity (2+1)

Aim of the Course

To learn and understand the microbial diversity in soils in the living world. To know various physical and chemical growth requirements of microbes. To get equipped with various methods of microbial growth measurement. To understand, learn and gain skills of isolation, culturing and maintenance of pure culture. To know various Culture media and their applications.

THEORY

Unit I

Microbial evaluation and biodiversity, Microbial communities in ecosystems, new insights in below ground diverse of plant performance. Qualitative ecology of microorganisms; Biomass and activities.

Unit II

Nitrogen fixing organisms, Trends in diversity of N fixing organisms. Molecular approaches in characterising N fixing microorganisms.

Unit III

Serology and molecular characterization, ecological aspects of bio determination, soil waste and water management

Unit IV

Biodegradability, testing and monitoring of the bioremediation of xerobiotic pollutants.

Unit-V

Bio fertilizers-definition, Bacterial Bio fertilizer, Fungal Biofertilizers, Phosphobacteria.

Algal Biofertilizers classification, specification, method of production and role in crop.

Practical

- Determination of soil microbes using classical techniques.
- Determination of soil microbial diversity using molecular techniques.
- Estimation of soil microbial biomass carbon, nitrogen and phosphorus.
- Estimation of key soil enzyme activities.
- Community level physiological profiling of microbial diversity

Learning Outcome

Experience on soil microbial diversity and planning for proper utilization.

Lecture Schedule

Unit I

1. Soil Biota and Evaluation
2. Microbial communities in ecosystems
3. Microbial diversity in the sub-soil
4. New insights in the diversity of microorganisms and plant performance
5. Molecular diversity of Microbes, Plant and their interactions.
6. Qualitative ecology of microorganisms
7. Environmental factors influencing the activities of microbes in soil.
8. Biomass and activities of microorganisms

Unit II

9. Microbial transformation of N in soil, nitrogen cycle.
10. Nitrogen fixing microorganisms
11. Diversity of N fixing organisms
12. Microbiology and biochemistry of Nitrogen fixation, root soil interface.
13. Rhizosphere and its importance to crop plants and R : S ratio.
14. Molecular approaches in characterising N fixing organisms.

Unit III

15. Serology and molecular characterization
16. Ecological aspects of bio determination
17. **Midsemester Examination**
18. Biochemical composition of soil organic matter and crop residues.
19. Biodegradation of soil organic matter and crop residues.
20. Organic wastes and its degradation.
21. Organic wastes as manures.

Unit IV

22. Biotic factors in soil development.
23. Microbial interactions in soil – Positive interactions.
24. Microbial interactions in soil – Negative interactions.
25. Microbial interactions in water – Positive interactions.
26. Microbial interactions in water – Negative interactions
27. Biodegradation of Pesticides – Insecticides
28. Biodegradation of herbicides and fungicides

Unit V

29**.** Bio fertilizers-definition- Bacterial Bio fertilizer- Rhizobium, Azospirillum Azotobacter and Phosphobacteria.

30. Fungal Biofertilizers, Algal Biofertilizers – BGA, Azolla.

31. Method of Biofertilizers production and applications.

32. Method of Biofertilizers applications.

33. Quality control of Biofertilizers.

34. Soil Enzyme activities and their importance.

Practical Schedule

1.Conn's Direct microscopic count for estimating soil microbial population.

2. Standard plate count of estimating soil microbial population.

3. Most probable number method for estimating soil microbial population.

4. Buried slide techniques.

5. Determination of soil microbial biomass using molecular techniques- I

6. Determination of soil microbial biomass using molecular techniques- II

7. Amylase production test (Demonstration of starch hydrolysis).

8. Cellulase production test (Degradation of cellulose).

9. Production of pectinolytic enzymes (Degradation of pectin).

10. Isolation of root nodule bacterium Rhizobium.

11. Isolation and purification of Azotobacter.

12. Estimation of Soil microbial biomass carbon

13. Estimation of Soil microbial biomass nitrogen

14. Estimation of Soil microbial biomass Phosphorus

15. Community level Physiological profiling of bacteria 1

16. Community level Physiological profiling of fungi and Rhizosphere study

17. Practical examination

Suggested Readings

1. Aneja K.R.2007. Experiments in Microbiology, plant pathology, Tissue culture and Mushroom Cultivation , New Age International, New Delhi

2. Atlas R.M. 1988. Microbiology – Fundamentals and Applications, Macmillan Publishing Company, New York.

3. Benson Harold J. 2002.Microbiological Applications, WCB McGraw – Hill, New York

4. Brock T.D. and Madigan M.T.2006. Biology of Microorganisms, Prentice Hall of India Private Limited

5. Martin Alexander. 1977. Introduction to Soil Microbiology. John Wiley Publication New Delhi.

6. Paul, EA. 2007. Soil Microbiology, Ecology and Biochemistry. 3rd Ed. Academic Press, New Delhi

7. Pelczar .J. Chan E.C.S. and Krieg N.R.2001. Microbiology, McGraw Hill Book Company, New York

8. Ravindra Nath, Fundamentals of Biology Courses for Biotechnology, - Vol.1, Special Bangalore University edition, Kalyani Publishers

9. Salle A.J. 2007. Fundamental Principles of Bacteriology, Tata McGraw – Hill Publishing Company Limited, New Delhi

10. Stanier R.Y., Ingraham J.L., 1999. General Microbiology, Prentice Hall of India Private Limited, New Delhi

Suggested Websites

1. https://www.biologydiscussion.com

2. https://www.veryshortintroductions.com

3. https://www.slideshare.net › biodiversity-and-microbial

Ph.D.
Vegetable Science

Ph.D. Vegetable Science

Sl No.	Course code	Course Title	Cr. Hr.
I.	**Major courses (12 credits)**		
01	VSC 601*	Recent trends in vegetable production	3+0
02	VSC 602*	Advances in breeding of vegetable crops	3+0
03	VSC 603	A biotic stress management in vegetable crops	2+1
04	VSC 604	Seed Certification, Processing and Storage of Vegetable Seeds	2+1
05	VSC 605	Breeding for Special Traits in Vegetable Crops	2+0
06	VSC 606	Biodiversity and conservation of vegetable crops	2+1
07	VSC 607	Biotechnological Approaches in Vegetable Crops	2+1
08	VSC 608	Advanced Laboratory Techniques for Vegetable Crops	1+2
II.	**Minor Courses (6 credits)**		
III.	**Supporting Courses (5 credits)**		
IV.	**Seminar (2 credits)**		
01	VSC 691	Doctoral Seminar	0+1
02	VSC 692	Doctoral Seminar	0+1
V.	**Thesis Research (75 credits)**		
01	VSC 699	Doctoral Research	0+75

* Courses to be compulsorily registered

VSC 601 Recent Trends in Vegetable Production (3+0)

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:

Theory

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, radish and cucurbits

Unit V

Tuber crops: Sweet potato, Cassava, elephant foot yam, Dioscorea and taro.

LectureSchedule

Unit I

1. Present status and prospects of vegetable cultivation
2. **Tomato -** 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.
3. **Brinjal -** 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.

4. **Brinjal -** 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.
5. **Chilli -** 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.
6. **Chilli -**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.
7. **Sweet pepper -** 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.
8. **Sweet pepper -** 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.
9. **Potato -** 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.
10. **Potato -** 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.

Unit II

11. **Cabbage -** 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.

12. **Cabbage -** 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.
13. **Cauliflower -** 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.
14. **Cauliflower -** 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.
15. **Knolkhol -** 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.
16. **Knolkhol** - 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.
17. **Sprouting broccoli -** 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.
18. **Sprouting broccoli -** 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.

Unit III

19. **Okra -** 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.

20. **Onion -** 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.
21. **Peas -** 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.
22. **Peas -** 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.
23. **Beans -** 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.
24. **Amaranth -** 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.
25. **Drumstick -** 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.

Unit IV

26. **Carrot -** 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.
27. **Carrot -** 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.
28. **Beetroot -** 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.
29. **Beetroot -**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.
30. **Turnip -** 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.
31. **Radish -** 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.

32. **Radish** -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.
33. **Cucurbits-** 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;
34. **Cucurbits** - physiological basis of growth, yield and quality as influenced by chemicals and growth regulators.
35. **Cucurbits** - 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.

Unit V

36. **Sweet potato** - 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.
37. **Cassava** - 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.
38. **Elephant foot yam** - 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.
39. **Elephant foot yam** -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.

40. **Dioscorea -** 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.
41. **Taro -** 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,
42. **Taro** -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.
43. Protected cultivation of vegetables,
44. Containerized culture for year-round vegetable production.
45. Low-cost polyhouse
46. Production of vegetables in net house.
47. Crop modelling,
48. Organic gardening.
49. Vegetable production for pigments,
50. Export and processing of vegetables

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

Suggested Reading

1. Bose, T. K and Som, N. G. 1986. *Vegetable crops of India*. Naya Prakash.
2. Bose T. K, Kabir, J, Maity, T.K. Parthasarathy, V. A and Som, M.G. 2003. *Vegetable crops*. Vols. I-III.Naya Udyog.
3. Brewster, J.L. 1994. *Onions and other vegetable alliums*. CABI.

4. Chadha, K.L and Kalloo, G. (Eds.). 1993-94. *Advances in horticulture* Vols. V-X. Malhotra Publ.House.
5. Chadha, K. L (Ed.). 2002. *Hand book of horticulture*. ICAR.
6. Chauhan, D.V. S (Ed.). 1986. *Vegetable production in India*. Ram prasad and Sons.
7. Fageria, M. S, Choudhary, B.R and Dhaka, R.S. 2000. *Vegetable crops: production technology*. Vol.II. Kalyani.
8. Ghosh, S.P, Ramanujam, T, Jos, J.S, Moorthy, S.N and Nair, R.G. 1988. *Tuber crops*. Oxford andIBH.
9. Gopalakrishanan, T.R. 2007. *Vegetable crops*. New India Publ. Agency.
10. Hazra, P and Som, M.G. 2015. *Seed production and hybrid technology of vegetable crops*. Kalyani Publishers, Ludhiana.
11. Hazra, P. 2016. *Vegetable science*. 2nd Edn, Kalyani publishers, Ludhiana.
12. Hazra P. 2019. *Vegetable production and technology*. New India Publishing Agency, New Delhi.
13. Kallo, G and Singh, K. (Ed.). 2001. *Emerging scenario in vegetable research and development*.Research periodicals and Book Publ. House.
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15. Rana, M.K. 2008. *Olericulture in India*. Kalyani Publishers, New Delhi.
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22. Singh, P.K, Dasgupta, S.K and Tripathi, S.K. 2006. *Hybrid vegetable development*. Internationalbook distr. Co.
23. Thamburaj, S and Singh, N. (Eds.). 2004. *Vegetables, tuber crops and spices*. ICAR.
24. Thompson, H.C and Kelly, W.C. (Eds.). 1978. *Vegetable crops*. Tata McGraw-Hill.

Suggested websites:

- https://www.researchgate.net/topic/Vegetable-Production/publications
- https://www.iihr.res.in/
- https://iivr.icar.gov.in/
- https://www.iari.res.in/index.php/en/
- https://avrdc.org/

VSC 602 Advances in Breeding of Vegetable Crops (3+0)

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:

Theory

Unit I

Solanaceous crops - Tomato, Brinjal, Hot Pepper, 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

Theory Schedule

Unit I

1. 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, biofortification,*in-vitro* breeding, marker assisted breeding, haploidy, development of transgenic of Tomato

2. Brinjal

3. Hot Pepper

4. Sweet pepper

5. Okra

6.Potato

Unit II

7. Pumpkin

8. Squashes

9. Cucumber
10. Ash gourd
11. Bitter gourd
12. Bottle gourd
13. Ridge gourd
14. Sponge gourd
15. Ivy gourd
16. Snake gourd
17. Watermelon
18. Muskmelon
19. Chow-chow
20. Cabbage
21. Cauliflower
22. Brussels sprout
23. Sprouting broccoli
24. Chinese cabbage
25&26. Knol khol

Unit III

27. Garden pea
28. Cowpea
29. Cluster bean
30. Indian bean
31. French bean
32. Broad bean
33. Amaranth
34. Palak
35. Spinach
36. Lettuce
37. Chekkurmanis
38. Moringa

Unit IV

39. Carrot
40. Beetroot

41. Radish

42. Turnip

43. Onion

44. Garlic

45. Leek

Unit V

46. Sweet potato

47. Tapioca

48. Elephant foot yam

49. Colocasia

50. Dioscorea

51. Artichoke

Learning outcome

After successful completion of this course, the students are exposed to:

• Breeding objectives and trends

• Recent Adavnces in vegetable breeding

Suggested readings:

1. Allard RW. 1999. *Principles of plant breeding*. John Wiley and Sons.
2. Basset MJ. (Ed.). 1986. *Breeding vegetable crops*. AVI Publ.
3. Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticulturalcrops*. Narosa Publ. House.
4. Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: Breeding and seed production*.Vol. I. Kalyani.
5. Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.
6. Hayes HK, Immer FR and Smith DC. 1955. *Methods of plant breeding*. McGraw-Hill.
7. Hayward MD, Bosemark NO and Romagosa I. (Eds.). 1993. *Plant Breeding-principles andprospects*. Chapman and Hall.
8. Hazra P and Som MG. 2015. *Vegetable science* (Second revised edition), Kalyani publishers,Ludhiana, 598p.
9. Hazra P and Som MG. 2016. *Vegetable seed production and hybrid technology* (Second revisededition), Kalyani Publishers, Ludhiana, 459p.
10. Kalloo G. 1988. *Vegetable breeding*. Vols. I-III. CRC Press.
11. Kalloo G. 1998. *Vegetable breeding*. Vols. I-III (Combined Ed.). Panima Edu. Book Agency.

12. Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. AgroBotanical Publ.
13. Paroda RS and Kalloo G. (Eds.). 1995. *Vegetable research with special reference to hybridtechnology in Asia-Pacific Region*. FAO.
14. Peter KV and Pradeepkumar T. 2008. *Genetics and breeding of vegetables.* Revised, ICAR.
15. Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium press LLC, P.O. Box722200, Houston, Texas 77072, USA, 678p.
16. 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.
17. 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.
18. Rai N and Rai M. 2006. *Heterosis breeding in vegetable crops*. New India Publ. Agency.
19. Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi.
20. Rout GR and Peter KV. 2008. *Genetic engineering of horticultural crops*. Academic press, Elsevier,USA.
21. Simmonds NW. 1978. *Principles of crop improvement*. Longman. Singh BD. 1983. Plant Breeding.Kalyani Publishers, New Delhi.
22. Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. InternationalBook Distributing Co.
23. Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

Suggested websites:

- https://www.britannica.com
- https://www.sesric.org
- https://agriinfo.in ›
- https://www.uidaho.edu
- https://icar.org.in
- https://agritech.tnau.ac.in
- https://www.researchgate.net ›
- https://annamalaiuniversity.ac.in
- http://ecoursesonline.iasri.res.in

- http://courseware.cutm.ac.in
- https://www.britannica.com

VSC 603 Abiotic Stress Management in Vegetable Crops (2+1)

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:

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 anti-transpirants in alleviation of different stresses.

LECTURE SCHEDULE

Unit - I

1. Biological Stress – Definition, classification and impact of abiotic stress and significance its management in vegetable crop production
2. Study of abiotic stress factors limiting vegetable crop production
3. Soil physical and chemical properties in relation to plant nutrient availability
4. Impact of deficiency and toxicity of major nutrients in vegetable crop production
5. Impact of deficiency and toxicity of mor nutrients in vegetable crop production
6. Classification of vegetable crops based on stress tolerance
7. Global warming – causes and impact on vegetable production

Unit - II

8. Oxidative stress and anti-oxidative defense mechanism in plants
9. Impact of drought and assessment of drought tolerance in vegetable crop production
10. Drought tolerance mechanism in vegetable crops
11. Drought stress management in vegetable crop production
12. Impact of water logging and its management in vegetable crop production
13. Soil salinity and sodicity – classification and current scenario
14. Mechanism of salt tolerance in plants

Unit - III

15. Role of wild species in vegetable crop production under abiotic stress
16. Vegetable grafting technique – a tool for abiotic stress management
17. Soil – plant - water relation under abiotic stress situations
18. Salinity management in vegetable crop production
19. Heat stress and mechanism of heat tolerance in vegetable crops
20. Management of heat stress in vegetable crop production
21. High temperature stress and its management in vegetable crop production

Unit - IV

22. Techniques of vegetable production under abiotic stress I (drought / heat)
23. Techniques of vegetable crop production under abiotic stress II (water logging / low temperature)
24. Techniques of vegetable crop production under abiotic stress III (salinity / sodicity)
25. Symptoms of frost injury and its tolerance mechanism in plants
26. Approaches for frost and low temperature management in vegetable crop production
27. Plant adaptation to stress

Unit - V

28. Role of protected structuresin abiotic stress management
29. Hydroponic vegetable crop production – an alternate approach under stressful environment
30. Aeroponic vegetable crop production – an alternate approach under stressful environment
31. Role of plant growth regulators in vegetable crop production under stress conditions
32. Significance of foliar nutrition in vegetable crop production under stress
33. Antitranspirants– types and significance in vegetable crop production

Practical Schedule

1. Identification of susceptibility and tolerance symptoms for drought in vegetable crops
2. Identification of susceptibility and tolerance symptoms for flooding in vegetable crops
3. Identification of susceptibility and tolerance symptoms for salinity in vegetable crops
4. Identification of susceptibility and tolerance symptoms for sodicity in vegetable crops
5. Identification of susceptibility and tolerance symptoms for heat stress in vegetable crops
6. Identification of susceptibility and toxicity symptoms for nutrients in vegetable crops
7. Measurement of drought tolerance in vegetable crops
8. Measurement of flooding tolerance in vegetable crops
9. Measurement of salinitiy tolerance in vegetable crops
10. Measurement of heat tolerance in vegetable crops
11. Studies on seed priming in stress alleviation
12. Studies on drought tolerance and susceptibility in vegetable crops
13. Studies on salinity tolerance and susceptibility in vegetable crops
14. Studies on heat tolerance and susceptibility in vegetable crops
15. Studies on the role of PGR in stress alleviation
16. Studies on chemical regulation of stress in vegetable crops
17. Experiment on hydroponic vegetable production
18. Final practical examination

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

Suggested Reading

1. Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. Plant genetic resources: horticulturalcrops. Narosa Publ. House.
2. Dwivedi P and Dwivedi RS. 2005. Physiology of abiotic stress in plants. Agrobios.
3. Janick JJ. 1986. Horticultural science. 4th Ed. WH Freeman and Co.
4. Kaloo G and Singh K. 2001. Emerging scenario in vegetable research and development. Researchperiodicals and book publ. house.
5. Kaloo G. 1994.Vegetable breeding. Vols. I-III. Vedams eBooks.
6. Lerner HR. (Eds.). 1999. Plant responses to environmental stresses. Marcel Decker.
7. Maloo SR. 2003. Abiotic stresses and crop productivity.Agrotech Publ. Academy.
8. Narendra T. et al. 2012. Improving crops resistance to abiotic stress. Wiley and Sons.US.

9. Peter KV and Pradeep Kumar T. 2008. Genetics and breeding of vegetables. (Revised Ed.). ICAR.
10. Peter KV and Hazra P. (Eds). 2015. Hand book of vegetables volume II.Studium Press LLC,
11. P.O. Box 722200, Houston, Texas 77072, USA, 509p.
12. 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.
13. Ram HH. 2001. Vegetable breeding. Kalyani.
14. Rao NK. (Eds.). 2016. Abiotic stress physiology of horticultural crops. Springer publication.

Suggested websites:

- www.plantphysiol.org./
- www.biologyonline.org/abiotic_stress
- www.plantsress.com
- http://www.uv.ac.uk/Nsol21/stress/drougnt.htm
- www.plantphysiol.org./

VSC 604 Seed Certification, Processing and Storage of Vegetable Seeds (2+1)

Aim of the course

To impart the knowledge on seed certification, processing and storage of vegetable seeds

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.

LECTURE SCHEDULE

Unit I

1. History and concept of seed certification
2. Role and functions of seed certification agency and organizational set up
3. Phases and procedures of seed certification
4. Indian minimum seed certification standards (IMSCS) - general seed certification standards
5. Planning and management of seed certification programmes

Unit II

6. Principles and methods of field inspection, counting procedures and reporting
7. Procedures for issue of liable for rejection (LFR) report, partial rejection and downgrading
8. Post-harvest inspection, processing report, reprocessing and method of assigning seed lot number
9. Seed sampling procedures, sampling intensity, types of samples and despatch to STL
10. Procedure for labeling, sealing and grant of certificate; types and specifications for tags and labels
11. Seed lot validity and revalidation procedures
12. OECD seed certification schemes

Unit III

13. Objectives and principles of seed processing
14. Sequence of seed processing for different crops
15. Principles and methods of seed drying
16. Methods of seed threshing, shelling and ginning
17.&18. Methods and machineries for seed cleaning, grading and upgrading
19. Specifications, design and layout of processing plant
20. Principles and methods of pre and mid storage seed treatments, seed treating formulations and equipments
21. Principles, concept and significance of seed quality enhancement techniques
22. Physical, physiological and biological seed quality enhancement techniques
23. Types of packaging materials, methods of bagging, labeling and stacking

Unit IV

24. Principles of seed storage and Harrington's thumb rule
25. Study on storage behaviour of orthodox and recalcitrant seeds
26. Types of storage - open, bulk, controlled and modified atmospheric storage, Germplasm storage, methods of cold storage and techniques of cryopreservation
27. Factors affecting seed longevity in storage (Pre and post harvest factors)

Unit V

28. Study on physical and physiological during seed storage
29. Study on biochemical and molecular changes during seed storage
30. Theories and causes for seed ageing and deterioration during storage
31. Maintenance of seed viability and vigour during storage
32. Method of seed storage

33. Study on seed storage structures

34. Maintenance of seed storage godown and transportation of seeds

PRACTICAL SCHEDULE

1. Preparation of sowing report for varieties and hybrids in transplanted and direct sown crops
2. Practicing online registration of seed farm
3. Field inspection - estimation of area and isolation distance
4. Practicing field counting procedures for row planting and broadcasted varieties and hybrids in row planting, block method and double count
5. Identification of genetic and physical contaminants and practicing roguing operations
6. Assessment of field standards for different crops and reporting
7. Practicing post-harvest inspection in Vegetable crops
8. Visit to seed processing unit, commercial seed stores and studying the procedures of maintaining registers and records
9. Practicing float test, preparation of processing report and assigning seed lot number
10. Practicing bagging, labelling and sealing of certified seed lots
11. Visit to regulatory seed testing
12. Visit to plant quarantine laboratories
13. Conducting physical purity analysis seed germination test, seedling evaluation and reporting results
14. Estimation of seed moisture content
15. Conducting seed germination test and seedling evaluation
16. Biochemical and molecular methods of genetic purity of assessment
17. **Final practical examination**

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

Suggested Reading

- Agarwaal PK and Anuradha V. 2018. *Fundamentals of seed science and technology*. Brilliant

publications, New Delhi.

- Basra AS. 2000. *Hybrid seed production in vegetables*. CRC press, Florida, USA.

- Bench ALR and Sanchez RA. 2004. *Handbook of seed physiology*. Food products press, NY/

London.

- Chakraborty SK, Prakash S, Sharma SP and Dadlani M. 2002. *Testing of distinctiveness,*

uniformity and stability for plant variety protection. IARI, New Delhi

- Copland LO and McDonald MB. 2004. *Seed science and technology*, Kluwer academic press.
- Fageria MS, Arya PS and Choudhry AK. 2000. *Vegetable crops: breeding and seed production*

Vol 1. Kalyani publishers, New Delhi.

- George RAT. 1999. *Vegetable seed production* (2nd Edition). CAB International.
- Hazra P and Som MG. 2016. *Vegetable seed production and hybrid technology* (Second revised

edition), Kalyani publishers, Ludhiana, 459p

- Kalloo G, Jain SK, Vari AK and Srivastava U. 2006. *Seed: A global perspective*. Associated

publishing company, New Delhi.

- Singhal NC. 2003. *Hybrid seed production*. Kalyani publishers, New Delhi.

Suggested websites:

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

VSC 605 Breeding for Special Traits in Vegetable Crops (2+0)

Aim of the course

To impart knowledge on recent developments in breeding for improved nutritional quality in important vegetable crops

Theory

Important nutrient constituents in vegetables and their role in human diet. Geneticsof nutrients. Genetic and genomic resources for improving quality traits invegetables, breeding strategies for developing varieties with improved nutrition formarket and industrial purposes. Molecular and biotechnological approaches inbreeding 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 qualitytraits in vegetable crops, bioavailability of dietary nutrients from improved vegetablecrops and impact on micronutrient malnutrition, achievements and future prospectsin breeding for quality traits in vegetables.

Theory Schedule

Unit I

1. Important nutrient constituents in vegetables and their role in human diet.
2. Genetics of nutrients. Genetic and genomic resources for improving quality traits in vegetables.
3. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in cole crops.
4. Molecular and biotechnological approaches in breeding suitable cultivars of cole crops for micronutrients and color content.

5. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in carrot.
6. Molecular and biotechnological approaches in breeding suitable cultivars of carrot for micronutrients and color content.
7. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in beetroot.
8. Molecular and biotechnological approaches in breeding suitable cultivars of beetroot for micronutrients and color content.

Unit II

9. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in tomato.
10. Molecular and biotechnological approaches in breeding suitable cultivars of tomato for micronutrients and color content.
11. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in brinjal.
12. Molecular and biotechnological approaches in breeding suitable cultivars of brinjal for micronutrients and color content.
13. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in peppers.
14. Molecular and biotechnological approaches in breeding suitable cultivars of peppers for micronutrients and color content.
15. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in potato.
16. Molecular and biotechnological approaches in breeding suitable cultivars of potato for micronutrients and color content**.**

Unit III

17. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in green leafy vegetables.
18. Molecular and biotechnological approaches in breeding suitable cultivars of green leafy vegetables for micronutrients and color content.
19. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in legume crops.

20. Molecular and biotechnological approaches in breeding suitable cultivars of legume crops for micronutrients and color content.
21. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in okra.
22. Molecular and biotechnological approaches in breeding suitable cultivars of okra for micronutrients and color content.

Unit IV

23. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in cucumber, pumpkin and squashes.
24. Molecular and biotechnological approaches in breeding suitable cultivars of cucumber, pumpkin and squashes for micronutrients and color content.
25. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in melons and gourds.
26. Molecular and biotechnological approaches in breeding suitable cultivars of melons and gourds for micronutrients and color content.
27. Breeding strategies for developing varieties with improved nutrition for market and industrial purposes in edible *Alliums*.
28. Molecular and biotechnological approaches in breeding suitable cultivars of edible *Alliums* for micronutrients and color content.

Unit V

29. Biofortification in vegetable crops.
30. Genetic engineering for improvement of qualitytraits in vegetable crops.
31. Bioavailability of dietary nutrients from improved vegetablecrops and impact on micronutrient malnutrition.
32. Achievements in breeding for quality traits in vegetables.
33. Future prospectsin breeding for quality traits in vegetables.

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

Suggested readings:

1. Allard RW. 1999. *Principles of plant breeding*. John Wiley and Sons.
2. Basset MJ. (Ed.). 1986. *Breeding vegetable crops*. AVI Publ.

3. Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticulturalcrops*. Narosa Publ. House.
4. Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: Breeding and seed production*.Vol. I. Kalyani.
5. Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.
6. Hayes HK, Immer FR and Smith DC. 1955. *Methods of plant breeding*. McGraw-Hill.
7. Hayward MD, Bosemark NO and Romagosa I. (Eds.). 1993. *Plant Breeding-principles andprospects*. Chapman and Hall.
8. Hazra P and Som MG. 2015. *Vegetable science* (Second revised edition), Kalyani publishers,Ludhiana, 598p.
9. Hazra P and Som MG. 2016. *Vegetable seed production and hybrid technology* (Second revisededition), Kalyani Publishers, Ludhiana, 459p.
10. Kalloo G. 1988. *Vegetable breeding*. Vols. I-III. CRC Press.
11. Kalloo G. 1998. *Vegetable breeding*. Vols. I-III (Combined Ed.). Panima Edu. Book Agency.
12. Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. AgroBotanical Publ.
13. Paroda RS and Kalloo G. (Eds.). 1995. *Vegetable research with special reference to hybridtechnology in Asia-Pacific Region*. FAO.
14. Peter KV and Pradeepkumar T. 2008. *Genetics and breeding of vegetables.* Revised, ICAR.
15. Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium press LLC, P.O. Box722200, Houston, Texas 77072, USA, 678p.
16. 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.
17. 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.
18. Rai N and Rai M. 2006. *Heterosis breeding in vegetable crops*. New India Publ. Agency.
19. Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi.
20. Rout GR and Peter KV. 2008. *Genetic engineering of horticultural crops*. Academic press, Elsevier,USA.

21. Simmonds NW. 1978. *Principles of crop improvement*. Longman. Singh BD. 1983. Plant Breeding.Kalyani Publishers, New Delhi.
22. Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. InternationalBook Distributing Co.
23. Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

Suggested websites

- https://www.intechopen.com
- https://www.botanylibrary.com
- https://eorganic.info
- https://videleaf.com

VSC 606 BIODIVERSITY AND CONSERVATION OF VEGETABLE CROPS (2+1)

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:

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 vegetable crop domestication; current status of germplasm availability/ databaseofvegetablecropsinIndia

Unit-II

Germplasmconservation:collection,maintenanceandcharacterization:Exploration and collection of germplasm; sampling frequencies; size and forms of vegetable germplasm collections; active and base collections. Germplasm conservation- insitu and ex situ strategies, on farm conservation; problem of recalcitrance- cold storage of scions, tissue culture, cryopreservation, pollen and seedstorage.

UnitI-II

Regulatoryhorticulture: Germplasm exchange, quarantine and intellectual property rights germplasm exchange, quarantine and intellectual property rights regulatory horticulture, inventory and exchange of vegetable crops germplasm.

Unit-IV

Plant quarantine, phyto-sanitary certification, detection of genetic constitution of germplasm and maintenance of core collection. IPRs, Breeder's rights, Farmer's rights, PPVand FR Act.

Unit-V

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 vegetable varieties in India.

THEORY SCHEDULE

UNIT I

1. Issues, goals and current status of Biodiversity in vegetable crops
2. Present status of National and International gene centres,needs and challanges, worlds major centre of vegetable crops
3. Current status of germplasm availability/database of vegetables in India
4. Principles of PGR exploration, collection,maintenance of vegetable crop germplasm

UNIT II

5. Conservation of genetic resources of vegetable crops
6. Centres of origin of cultivated vegetables, geographical distribution of vegetable crops of Indian origin
7. Methods of ex - situ conservation of vegetable crops germplasm
8. Methods of in situ conservation of vegetable crops germplasm
9. Advances and issues in conservation of biodiversity recalcitrant and orthodox seeds
10. Advances and issues in conservation of biodiversity of vegetative propagation
11. Cryopreservation of pollen and seeds of vegetable crops

UNIT III

12. Inventory of germplasm, introduction of germplasm
13. Components of gene bank-seed gene bank , field gene bank,invitro repository, Cryogene bank DNA library an herbarium
14. Intellectual property rights, Plant Variety Protection Authority (Breeder right, Farmers right, PPV and FR Act)

Unit IV

15. Plant quarantine, phyto sanitary certification, detection of genetic constitution of germplasm and maintenance of core collection
16. GIS and documentation of local biodiversity

Unit V

17. Geographical indication, GIS application in horticultural mapping and spatial analysis of field data.
18. Benefits of Geographical indication protection, GI tagged vegetables and its variety in India
19. Origin, distribution, classification, description and botany of tropical and subtropical vegetable crop dynamics of domestication
20. Origin, distribution, classification, description and botany of temperate vegetable crop dynamics of domestication

21. Status of biodiversity of potato
22. Status of biodiversity of Solanaceous vegetables
23. Status of biodiversity of Okra
24. Status of biodiversity of cucurbitaceous vegetables
25. Status of biodiversity of melon and pepo
26. Status of biodiversity of cruciferous crops
27. Status of biodiversity of root crops
28. Status of biodiversity of tuber crops
29. Status of biodiversity of bulb crops
30. Status of biodiversity of legume vegetables
31. Status of biodiversity of leafy vegetables
32. Status of biodiversity of perennial vegetables
33. Policy issues: assessing economic values, conflict over ownership, management and use Data documentation techniques

Practical schedule

1. Field exploration trips- Exercise in collection and characterization
2. Visit to field germplasm unit and documentation of germplasm
3. Practices in maintenance of passport data
4. Practical study of ex situ conservation methods for vegetable crops
5. Practical study of in situ conservation methods for vegetable crops
6. Methods of seed storage for short and long term conservation for vegetable crops
7. Methods of conservation using vegetative propagules
8. In vitro conservation protocols for vegetable crops
9. Study of species diversity in horticultural cropping system
10. Visit to regional conservation centres
11. Characterization of Solanaceousand cruciferous vegetable germplasm
12. Characterization of cucurbitaceous and leafy vegetable germplasm
13. Characterization of tuber and root vegetable germplasm
14. Characterization of legume and bulb vegetable germplasm
15. Use of molecular tools for characterizing species diversity
16. Estimating extent of diversity through collection and analyses of data

17. Final Practical Examination

Learning outcome

- The student would be expected to learn about the significance of germplasm
- Various strategies to conserve it in the present context.

Suggested Reading

1. Dhillon BS, Tyagi RK, Lal A and Saxena S. 2004. *Plant genetic resource management.* _
2. *horticultural crops*. Narosa publishing house, New Delhi.
3. Engles JM, Ramanath RV, BrowFrankel OH and Hawkes JG. 1975. *Crop genetic resources for today and tomorrow*. Cambridge University Press, USA.
4. Hancock J. 2012. *Plant evolution and the origin of crops species.* CAB International.
5. Jackson M, Ford-Lloyd B and Parry M. 2014, *Plant genetic resources and climate change*. CABI, Wallingford, UK
6. Moore JN and Ballington JR. 1991. *Genetic resources of temperate Fruit and nut crops*. ISHS,
7. Belgium.
8. Peter KV. 2008. *Biodiversity of horticultural crops*. Vol. II. Daya Publ. House, Delhi.
9. Peter KV. 2011. *Biodiversity in horticultural crops*. Vol.III. Daya Publ. House, Delhi.
10. Rajasekharan PE, Rao V and Ramanatha V. 2019. *Conservation and utilization of horticultural*
11. *genetic resources*. Springer.
12. Rana JC and Verma VD. 2011. *Genetic resources of temperate minor fruits (indigenous andexotic*). NBPGR, New Delhi.
13. Sthapit *et al.* 2016. *Tropical fruit tree diversity* (*good practices for in situ and ex situ conservation*). Bioversity international. routledge, Taylor and Francis Group.
14. Virchow D. 2012. *Conservation of genetic resources*, Springer Verlag, Berlin

Suggested websites:

- http://www.nbpgr.ernet.in/
- https://cgspace.cgiar.org/handle/10568/45742

VSC 607 Biotechnological Approaches in Vegetable Crops (2+1)

Aim of the course

To impart latest knowledge in biotechnical advancement in vegetable crops

The course is organised as follows:-

Unit I

Importance and scope of biotechnology – in vegetable crop improvement. *In-vitro*-culture, micro-propagation, anther culture, pollen culture, ovule culture, embryoculture, endosperm culture.

Unit II

Somatic embryogenesis – somaclonal variation and synthetic seed production,protoplast isolation, culture, manipulation and fusion. Somatic hybrids and cybridsand their application in vegetable improvement programme.

Unit III

Blotting techniques, DNA finger printing – Molecular markers/ DNA based markersand role. RFLP, AFLP, RAPD, SSR, SNPs, DNA probes. QTL mapping. MAS andits 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 genetransfer. Role of RNAi based gene silencing in vegetable crop improvement. Biosafetyissue, regulatory issues for commercial approval.

Unit V

Concepts and methods of next generation sequencing (NGS)- Genome sequencing,transcriptomics, proteomics, metabolomics. Genome editing (ZFN, TALENS andCRISPER)

Crops

Solanaceous crops, cole crops, cucurbitaceous crops, root vegetables, garden pea, onion, potato and leafy vegetables

LECTURE SCHEDULE

UNIT – I

1. Scope and Importance of biotechnology in vegetable crop improvement

2. Invitro and micro propagation in vegetable crops

3. Anther & Pollen culture in vegetable crops

4. Ovule & Embryo culture in vegetable crops

5. Endosperm and meristem culture in vegetable crops

UNIT- II

6. Somatic embryogenesis in vegetable crops

7. Somaclonal variation for vegetable crop improvement

8. Micro-grafting in vegetable crops

9. Protoplast isolation, culture and fusion in vegetable crops

10. Somatic hybrids and their application in vegetable crop improvement

11. Cryopreservation and its application in vegetable crops

12. Synthetic seed production in vegetable crops

UNIT- III

13. Importance and application of Blotting techniques

14. Importance and application of DNA finger printing

15. Importance of molecular markers

16. &17. Application of DNA based markers in vegetable crops-I

18. Application of DNA based markers in vegetable crops-II

19. Importance of QTL mapping in vegetable crop improvement

20. MAS and its application in vegetable crop improvement.

21. Allele mining by TILLING and Eco-TILLING.

UNIT - IV

22. Plant genetic engineering - Scope and importance

23. Concepts of cisgenesis, intragenesis and transgenesis.

24. Application of transgenics in development of varieties for resistance

25. Application of transgenics in development of varieties for quality improvement

26. Gene cloning techniques

27. Bio-safety, regulatory issues for commercial approval.

UNIT- V

28. Application of genome editing in vegetable crop improvement

29. Application of genome editing in vegetable crop improvement

30. Role of RNAi based gene silencing in vegetable crop improvement.

31. Concepts and methods of next generation sequencing (NGS)

32. Transcriptomics in vegetable crop improvement

33. Proteomics in vegetable crops

34. Metabolomics in vegetable crops

PRACTICAL SCHEDULE

1. Introduction to micro-propagation

2. In vitro shooting and rooting

3. Pollen culture method

4. Ovule culture method

5. Embryo culture method

6. Synthetic seed production

7. Induction of in vitro mutation

8. Hardening of plantlets

9. Isolation of DNA from economically important vegetable crop varieties

10. Quantification and amplification of DNA

11. DNA and Protein profiling

12. Use of molecular markers for characterization

13. Genetic transformation techniques

14. Genome editing procedures

15. Visit to commercial TC units

16. Project preparation for establishment of low,medium and high cost tissue culture laboratories

17. Final practical examination

Learning outcome

The student would be expected to learn

• Different biotechnological tools

• NGS, genetic engineering

Suggested Reading

1. Bajaj YPS. (Ed.). 1987. *Biotechnology in agriculture and forestry*. Vol. XIX. Hitech andMicropropagation. Springer.
2. Chadha KL, Ravindran PN and Sahijram L. (Eds.). 2000. *Biotechnology of horticulture andplantation crops*. Malhotra Publ. House.
3. Debnath M. 2005. *Tools and techniques of biotechnology*. Pointer publication, New Delhi.
4. Glover MD. 1984. *Gene cloning: the mechanics of DNA manipulation*. Chapman and Hall.
5. Gorden H and Rubsell S. 1960. *Hormones and cell culture*. AB Book Publ.
6. Keshavachandran R. 2007. *Recent trends in biotechnology of horticultural crops*. New IndiaPubl. Agency.
7. Keshavachandran R and Peter KV. 2008. *Plant biotechnology; tissue culture and gene transfer*.Orient and Longman, USA.
8. Keshavachandran R. 2007. *Recent trends in biotechnology of horticultural crops*. New-IndiaPublication Agency, New Delhi.
9. Panopoulas NJ. (Ed.). 1981. *Genetic engineering in plant sciences*. Praeger Publ.
10. Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK and Mohanadas S. 2001. *Biotechnologyof horticultural crops*. Vols. I-III. NayaProkash.
11. Pierik RLM. 1987. *In-vitro culture of higher plants*. MartinusNijhoff Publ.
12. Prasad S. 1999. *Impact of plant biotechnology on horticulture*. 2nd Ed. Agro Botanica.
13. Rout GR and Peter KV. 2018. *Genetic engineering of horticultural crops*. Academic Press Elsveer,USA.
14. Sharma R. 2000. *Plant tissue culture*. Campus Books.
15. Singh BD. 2010. *Biotechnology- expanding horizons*. Kalyani Publishers, New Delhi.
16. 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.

17. Vasil TK, Vasi M, While DNR and Bery HR. 1979. *Somatic hybridization and genetic*
manipulation in plants, plant regulation and world agriculture. Planum Press.

Suggested websites:

- http://vric.ucdavis.edu
- https://icar.org.in
- https://www.hrpub.org
- https://www.ijcmas.com
- https://www.actahort.org

VSC 608 Advanced Laboratory Techniques for Vegetable Crops (1+2)

Aim of the course

To familiarize with the laboratory techniques for analysis of vegetable crops.

The organisation of the course is as under:

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.

Theory schedule

UNIT- I

1. Good laboratory practices- Safety measures and laboratory maintenance: Safety aspects and upkeep of laboratory
2. Sampling procedures for quantitative analysis
3. Preparation of stock and standard solutions for analysis
4. Calibration of instruments
5. Standardization of instruments
6. Textural properties of harvested produce - Assessment of TSS, specific gravity, pH and acidity

UNIT- II

7. Destructive and non-destructive analysis methods: Refractometry
8. Destructive and non-destructive analysis methods: spectrophotometry
9. Destructive and Non-destructive determination of colour, ascorbic acid, sugars, and starch in food crops

UNIT- III

10. Chromatographic Analysis-Basic chromatographic techniques, GC, HPLC, GCMS, Electrophoresis techniques and ultra-filtration
12. Application of nuclear techniques in harvested produce for extending shelf-life
13. Advanced microscopic techniques - Scanning Electron Microscope (SEM)
14. Advanced microscopic techniques - Transmission Electron Microscope (TEM)
15. Advanced microscopic techniques- Phase contrast microscope

UNIT- IV

16. Sensory Analysis in fruit crops
17. Sensory analysis techniques- control for test room, products and panel

PRACTICAL SCHEDULE

1. Safety measures in labs and handling of chemical substances
2. Common laboratory equipments.
3. Calibration and cleanliness of volumetric glass wares.
4. Methods of expressing strength of solutions.
5. Preparation of primary standard solutions and buffer solutions.
6. Preparation of standard solutions for nutrient analysis of soil, plant and water.
7. Preparation of different agro-chemical doses for field experiments, preparation of buffer solutions.
8. Handling of instruments.
9. Determination of moisture.
10. Determination of relative water content.
11. Determination of physiological loss in weight.
12. Calibration and standardization of instruments.
13. Textured properties of harvested produce.
14. Determination of TSS, pH and acidity.
15. Determination of fibre.
16. Determination of protein.

17. Determination starch index (SI).
18. Determination of specific gravity for maturity assessment.
19. Detection of adulterations in fresh products.
20. Detection of adulterations in processes products.
21. Introduction of destructive and non-destructive analysis methods.
22. Non- destructive determination of colour.
23. Non-destructive determination of ascorbic acid.
24. Non-destructive determination of vitamins.
25. Non-destructive determination of carotenoids.
26. Non-destructive determination of sugars and starch.
27. Introduction on chromatographic and microscopic c analysis.
28. Study of basic chromatographic techniques.
29. Study of GC, HPLC and GCMS.
30. Study of electrophoresis techniques and ultra-filtration.
31. Introduction on advanced microscopes.
32. Use of advanced microscope-Fluorescent microscope.
33. Use of advanced microscope – Scanning electron microscope and phase contrast microscope.
34. Practical examination

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

Suggested Reading

1. AOAC International. 2003. Official methods of analysis of AOAC international. 17th Ed. Gaithersburg, MD, USA, association of analytical communities, USA.

2. Clifton M and Pomeranz Y. 1988. Food analysis – laboratory experiments. AVI publication, USA. Linskens HF and Jackson JF. 1995. Fruit analysis. Springer.

3. 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.

4. Ranganna S. 2001. Handbook of analysis and quality control for fruit and vegetable products.

2nd Ed. Tata-McGraw-Hill, New Delhi.

5. Thompson AK. 1995, Postharvest technology of fruits and vegetables. Blackwell sciences. USA

Suggested websites:

- https://agricoop.nic.in/sites/default/files/ICAR_7.pdf
- https://www.iihr.res.in/division-vegetable-crops
- https://www.researchgate.net/publication/338734798_Advanced_Breeding_Tools_in_Vegetable_Crops
- https://www.fao.org/3/i3284e/i3284e.pdf