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

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.
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.
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8. Frankel, R and Galun, E. 1977. Pollination Mechanisms, Reproduction and Plant Breeding. Springer Verlag, New York.
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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.
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15. Mondal, S.S., Saha, M. and Sengupta, K. 2009. Seed Production of Field Crops. New India Publishing Agency, New Delhi.
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17. Dadlani M and Yadava DK. 2023. Seed Science and Technology – Biology, Production, Quality. Springer: Verlag, Singapore.

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

1. Anon, 2016. Manual of Seed Certification Procedures. Directorate of Seed Certification, Coimbatore, Tamil Nadu.
2. Chakrabarthi, S.K. 2010. Seed Production and Quality Control. Kalyani Publishers, New Delhi.
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.
4. ISTA. 2010. Handbook of Variety Testing. International Seed Testing Association, Zurich, Switzerland.
5. Joshi, A. K. and Singh, B. D. 2004. Seed Science and Technology, Kalyani Publishers, New Delhi.
6. Maiti, R. K., Sarkar, N. C. and Singh, V. P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur.
7. Mishra, D. K., Khare, D., Bhale, M.S. and Koutu, G.K. 2011. Hand Book of Seed Certification. Agrobios, Jodhpur, Rajasthan.
8. Ramamoorthy, K., Sivasubramaniam, K. and Kannan, M. 2006. Seed Legislation in India. Agrobios, Jodhpur, Rajasthan.
9. Trivedi, P. C. 2011. Seed Technology and Quality Control. Pointer Publishers, Jaipur, Rajasthan.

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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4. Biocommunication: Sign-Mediated Interactions Between Cells and Organisms by Richard Gordon (Editor), Joseph Seckbach (Editor), 2017, World Scientific Publishing Europe Ltd ISBN-13: 9781786340443
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6. Chow, B. and McCourt, P., 2006. Plant hormone receptors: perception is everything. Genes and development, 20(15), pp.1998-2008.
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15. Hedden, P. and Thomas, S.G. eds., 2008. Annual Plant Reviews, Plant Hormone Signaling (Vol. 24). John Wiley and Sons.
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17. Huber, A.E. and Bauerle, T.L., 2016. Long-distance plant signaling pathways in response to multiple stressors: the gap in knowledge. Journal of Experimental Botany, 67(7), pp.2063- 2079.
18. Inaba, T., Yazu, F., Ito-Inaba, Y., Kakizaki, T. and Nakayama, K., 2011. Retrograde signaling pathway from plastid to nucleus. In International review of cell and molecular biology (Vol. 290, pp. 167-204). Academic Press.
19. Kami, C., Lorrain, S., Hornitschek, P. and Fankhauser, C., 2010. Light-regulated plant growth and development. In Current topics in developmental biology (Vol. 91, pp. 29-66). Academic Press.
19. Khan, M.I.R., Reddy, P.S., Ferrante, A. and Khan, N.A. eds., 2019. Plant Signaling Molecules: Role and Regulation Under Stressful Environments. Woodhead Publishing.
20. Laszlo Bogre and Gerrit Beemster, 2008. Plant cell monographs. Plant Growth Signaling.
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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

1. Pieruschka, R., and Poorter, H. (2012). Phenotyping plants: genes, phenes and machines. Functional Plant Biology, 39(11), 813-820.
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36. Capture: genomic and environment modelling of plant phenomic data. Current opinion in plant biology, 18, 73-79.
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38. Rahaman, M., Chen, D., Gillani, Z., Klukas, C., and Chen, M. (2015). Advanced phenotyping and phenotype data analysis for the study of plant growth and development. Frontiers in plant Science, 6, 619.
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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.
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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.
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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.

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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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17. Kahl G and Khalid M (eds.). 2008. The handbook of plant functional genomics: concepts and protocols. John Wiley and Sons.

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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.