

PONDICHERRY UNIVERSITY
SYLLABUS FOR ENTRANCE EXAMINATION
(Ph. D in Genetic and Plant Breeding)

Principles of Genetics

- Beginning of genetics; Early concepts of inheritance, Mendel's laws; Discussion on Mendel's paper, Chromosomal theory of inheritance. Multiple alleles, Gene interactions. Sex determination, Dosage compensation, sex differentiation and sex-linkage, Sex-influenced and sex-limited traits; Penetrance and expressivity; Linkage-detection, estimation; Recombination and genetic mapping in eukaryotes, Somatic cell genetics, Extra chromosomal inheritance.
- Mendelian population – Random mating population - Frequencies of genes and genotypes-Causes of change: Hardy-Weinberg equilibrium-assumptions, proof and testing, extension of Hardy-Weinberg equilibrium. Random and non-random mating, inbreeding, pedigree analysis and population analysis. Nature, structure and replication of the genetic material; Organization of DNA in chromosomes, Genetic code; Protein biosynthesis.
- Genetic fine structure analysis, Allelic complementation, Modern concept of genes- Split genes, Overlapping genes, Pseudogenes, Oncogenes, Gene families and clusters. Regulation of gene activity in prokaryotes; Molecular mechanisms of mutation, repair and suppression; types of mutation, molecular mechanism of mutation, classification of mutagens.
- Bacterial plasmids, insertion (IS) and transposable (Tn) elements; Molecular chaperones and gene expression. Gene regulation in eukaryotes, RNA editing. Gene isolation, synthesis and cloning, genomic and cDNA libraries, PCR-based cloning, positional cloning; Nucleic acid hybridization and immuno-chemical detection; DNA sequencing; DNA restriction and modification, Anti-sense RNA and ribozymes; Micro-RNAs (miRNAs).
- Genomics and proteomics; Functional and pharmacogenomics; Metagenomics. Methods of studying polymorphism at biochemical and DNA level; Transgenic bacteria and bioethics; Gene silencing; genetics of mitochondria and chloroplasts. Concepts of Eugenics, Epigenetics, Genetic disorders and Behavioural genetics.

Principles of Plant Breeding

- History of Plant Breeding (Pre- and post-Mendelian era); Objectives of plant breeding, characteristics improved by plant breeding; Patterns of Evolution in Crop Plants- Centres of Origin, Agro-biodiversity and its significance. Pre breeding and Plant Introduction and role of Plant Genetic resources in Plant breeding. Reproduction systems and pollination systems in plant breeding.
- Heritability and genetic advance, genotype-environment interaction; General and specific combining ability effects and variances; Types of gene actions and implications in plant breeding; Components of phenotypic value and components of variance and implication in plant breeding. Self-incompatibility and male sterility in crop plants and their commercial exploitation.
- Genetic basis of breeding self- and cross - pollinated crops including mating systems and response to selection - nature of variability. Breeding methods in self-pollinated crops. Pure line theory, pure line selection and mass selection methods; Line breeding, pedigree, bulk, backcross, single seed descent and multiline method; Population breeding in self-pollinated crops (diallel selective mating approach).
- Breeding methods in cross pollinated crops; Population breeding-mass selection and ear-to-row methods; S1 and S2 progeny testing, progeny selection schemes, recurrent selection schemes for intra and inter-population improvement and development of synthetics and composites. Hybrid breeding-genetical and physiological basis of heterosis and inbreeding, production of inbreds, breeding approaches for improvement of inbreds, predicting hybrid performance; seed production of hybrid and their parent varieties/inbreds.
- Breeding methods in asexually/clonally propagated crops, clonal selection apomixes, clonal selection. Concept of plant ideotype and its role in crop improvement; Transgressive breeding. Special breeding techniques- Mutation breeding; Breeding for abiotic and biotic stresses. Cultivar development- testing, release and notification, maintenance breeding, Participatory Plant Breeding, Plant breeders' rights and regulations for plant variety protection and farmers rights

Principles of Quantitative Genetics

- Introduction and historical background of quantitative genetics, Multiple factor hypothesis, Qualitative and quantitative characters, Analysis of continuous variation mean, range, SD, CV; Components of variation- Phenotypic, Genotypic, Nature of gene action- additive, dominance and epistatic, linkage effect. Principles of analysis of variance and linear model, Expected variance components, Random and fixed effect model, Comparison of means and variances for significance.
- Basic concepts Hardy- Weinberg law - Frequencies of genes and genotypes-Causes of change: population size, differences in fertility and viability, migration and mutation, mating system – Applications of the Hardy-Weinberg law. Analysis of continuous variation; Variations associated with polygenic traits - phenotypic, genotypic and environmental - non-allelic interactions.
- Designs for plant breeding experiments- principles and applications; Nature of gene action - additive, dominance, epistatic and linkage effects. Principles of Analysis of Variance (ANOVA) - Expected variance components, random and fixed models; MANOVA. Comparison of means and variances for significance. Association analysis- Genotypic and phenotypic correlation, Path analysis
- Mating designs- classification, Diallel, partial diallel, $L \times T$, NCDs, and TTC; Concept of combining ability and gene action, $G \times E$ interaction-Adaptability and stability; Methods and models for stability analysis; Basic models- principles and interpretation, Bi-plot analysis. Discriminate function and principal component analysis, Genetic divergence analysis- Metroglyph and D^2 , Generation mean analysis, Parent progeny regression analysis.
- QTL mapping, Strategies for QTL mapping- Desired population and statistical methods, QTL mapping in genetic analysis; Markers, Marker assisted selection. Approaches to apply MAS in Plant breeding - selection based on marker - simultaneous selection based on marker and phenotype - factors influencing MAS.

PRINCIPLES OF CYTOGENETICS

- Cell cycle and architecture of chromosome in prokaryotes and eukaryotes - Chromonemata, chromosome matrix, chromomeres, centromere, secondary constriction and telomere - artificial chromosome construction and its uses; Special types of chromosomes. Variation in chromosome structure: Evolutionary significance; Introduction to techniques for karyotyping – Chromosome banding and painting - in situ hybridization and various applications.
- Structural and numerical variations of chromosomes and their implications; Symbols and terminologies for chromosome numbers, euploidy, haploids, diploids and polyploids; Utilization of aneuploids in gene location; Variation in chromosome behaviour, somatic segregation and chimeras, endomitosis and somatic reduction; Evolutionary significance of chromosomal aberrations, balanced lethal and chromosome complexes; Inter-varietal chromosome substitutions.
- Fertilization barriers in crop plants at pre and post-fertilization levels; In vitro techniques to overcome the fertilization barriers in crops; Polyploidy. Genetic consequences of polyploidization and role of polyploids in crop breeding; Evolutionary advantages of autopolyploid vs allopolyploids; Role of aneuploids in basic and applied aspects of crop breeding, their maintenance and utilization in gene mapping and gene blocks transfer.
- Alien addition and substitution lines , creation and utilization; Apomixis , evolutionary and genetic problems in crops with apomixes. Reversion of autopolyploid to diploids; Genome mapping in polyploids; Interspecific hybridization and allopolyploids; Synthesis of new crops (wheat, triticale, brassica, and cotton); Hybrids between species with same chromosome number, alien translocations; Hybrids between species with different chromosome number.
- Gene transfer using amphidiploids and bridge species. Chromosome manipulations in wide hybridization; case studies; Production and use of haploids, dihaploids and doubled haploids in genetics and breeding.

MOLECULAR BREEDING AND BIOINFORMATICS

- 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); 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.
- 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 & sequencing by Edman degradation & 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; 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 & secondary), implications in crop improvement. Data management of Plant Genetic Resources.

Crop Breeding-I (*Kharif* Crops)

- **Rice:** Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives : yield, quality characters, biotic and abiotic stress resistance etc., Breeding approaches, introgression of alien gene(s), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement, Aerobic rice, its implications and drought resistance breeding. Maize:- Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives : yield, quality characters, biotic and abiotic stress resistance etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement- QPM and Bt maize – strategies and implications. Sorghum, Pearl millet and Small millets: Evolution and distribution of species and forms - wild relatives and germplasm; Cytogenetics and genome relationship - breeding objectives yield, quality characters, biotic and abiotic stress resistance. Pseudocereals.

- **Pigeonpea:** evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives : yield, quality characters, biotic and abiotic stress resistance etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement - Hybrid technology; maintenance of male sterile, fertile and restorer lines, progress made at National and International institutes. Groundnut: Origin, evolution mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship, breeding objectives: yield, quality characters, biotic and abiotic stress resistance etc.; Breeding approaches, introgression of alien gene(s), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement Other pulses: Urdbean, mungbean, cowpea: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship, breeding objectives : yield, quality characters, biotic and abiotic stress resistance etc.; Breeding approaches, introgression of alien gene(s) (if required), released varieties, examples of MAS used for improvement. Interspecific crosses attempted and its implications, reasons for failure, ways of overcoming them.
- **Soybean:** Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance etc.; Breeding approaches, introgression of alien gene(s), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement Castor and Sesame: Origin, evolution mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance etc.; Breeding approaches, introgression of alien gene(s), released varieties, examples of MAS used for improvement; Hybrid breeding in castor – opportunities, constraints and achievements.
- **Cotton:** Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives : yield, quality characters, biotic and abiotic stress resistance etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement, Development and maintenance of male sterile lines – Hybrid development and seed production – Scenario of Bt cottons, evaluation procedures for Bt cotton. Jute: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance etc.; Breeding approaches, introgression of alien gene(s), biotic and abiotic stress resistance, heterosis

breeding, released varieties, examples of MAS used for improvement.

- **Sugarcane:** Evolution and distribution of species and forms , wild relatives and germplasm; Cytogenetics and genome relationship – Breeding objectives- yield, quality characters, biotic and abiotic stress resistance etc. – Forage crops: Evolution and distribution of species and forms – Wild relatives and germplasm; Cytogenetics and genome relationship; Breeding objectives- yield, quality characters and palatability studies; Biotic and abiotic stress resistance etc., Seed spices : Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives : yield, quality characters, biotic and abiotic stress resistance etc.,; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement; Achievements of important spice crops.

Germplasm Characterization and Evaluation

- Understanding genetic diversity in crop plants; Crop descriptors, descriptor states; germplasm characterization/ evaluation procedures; evaluation of germplasm for specific traits.
- Measuring diversity using agro-morphological data, statistical procedures to measure population genetic variation, markers and their use in PGR, evaluation of biotic and abiotic stresses, Principles and methods for formulating core and mini core collections and their validation, Web based tools for management of data.
- Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces.
- Evaluation and maintenance of wild relatives of crop plants. Genetic enhancement, Use of CWRs genetic resources for crop improvement.
- High throughput phenotyping systems- imaging & image processing concepts for automated germplasm characterization (phenotyping) – evaluation for nutritional traits, resistance traits - Biochemical and molecular markers for characterization.