M.F.Sc & PhD Programs in Fish Genetics & Breeding - Syllabus

Indian Council of Agricultural Research
New Delhi
## COURSES

### M.F.Sc. (Fish Genetics and Breeding)

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### Ph.D. (Fish Genetics and Breeding)

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<td>Advances in Cytogenetics</td>
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M.F.Sc. (Fish Genetics and Breeding) SYLLABUS
MAJOR - CORE COURSES

FGB 501 PRINCIPLES OF GENETICS AND BREEDING 2+1

Objective
To understand the basic principles of genetics and breeding and their application to fisheries management and aquaculture.

Theory

Unit I  Historical development of genetics and Physical basis of heredity; Mendelian principles: scope, limitation, probability of Mendelian inheritance; Modifications to Mendelian ratios.

Unit II  Genetic variation: causes and measurement; Chromosome theory of inheritance: genetic basis of determination of sex.

Unit III Chromosome manipulation - ploidy induction, sex reversal, gynogenesis and androgenesis; Multiple alleles.

Unit IV  Linkage and crossing over, recombination, interference .

Unit V  Modern concept of gene; DNA as genetic material, genetic code and protein synthesis, transfer and regulation of genetic information.

Unit VI  Pleiotropy; Penetrance; Gene and genotypic frequency and factors affecting them, application of selection for performance improvement.

Unit VII  Mutation: natural and induced, mutagens fate of mutant allele in the population; Cross breeding and genetic drift.

Practical
Exercises on Mendelian laws, multiple alleles and epistasis; Practical demonstration of chromosome manipulations, Linkage and crossing over, ploidy induction; Induction of gynogenesis and androgenesis; Sex reversal.

Suggested Readings
1. Principles of Genetics: 2nd Ed. Snustad & Simmons;
2. Genetics for Fish Hatchery Managers : 2nd Ed. Douglas Tave;
3. Genetic bases of fish selection: V.S.Kirpichnikov;
4. Fish genetics and Biotechnology: W.S.Lakra;
5. Genetics and Fish Breeding: C.E.Purdom;
6. Practical Genetics for Aquaculture: C. Greglutz
8. Genetics and Analysis of Quantitative Traits: Lynch M, Walsh B.
Journals
1. Journal of Animal Breed and Genetics
2. Journal of Genetics
3. Journal of Heredity
4. Indian Journal of Genetics and Plant Breeding

Broad Research Areas
1. Cryopreservation of gametes of species of commercial importance
2. Ploidy induction in fishes
3. Production of mono sex population

FGB 502 POPULATION GENETICS 2+1

Objective
Understanding the concepts of population and its structure for fisheries management and aquaculture

Theory

Unit I Genetics of population: individual vs. population, genetic structure of random mating populations.

Unit II Hardy Weinberg principles: test of equilibrium, application and properties of equilibrium populations; Change in gene frequency under migration, mutation and selection; Effect of small population on gene frequency.

Unit III Estimation of HW principle/equilibrium using various population genetic tools: phenotypic, protein, and DNA markers.

Unit IV Coefficient of genetic differentiation – $F_{ST}$, $R_{ST}$, $Q_{ST}$, $G_{ST}$ - their relative merits and demerits, Genetic similarity and distance.

Unit V Genetic bottleneck and concept of Mutation drift equilibrium; Null alleles; Theory of path coefficients and analysis.

Unit VI Basis of relationships: independent and correlated causes; Inbreeding: types, methods of estimation and consequences; Genetic drift; Effective population size.

Practical
Exercises on various statistical procedures with emphasis on non-parametric distributions; Estimation of gene and genotype frequencies; Estimation of effect of mutation, migration and selection on equilibrium; Equilibrium in sex linked genes; Estimation of effective population size, rate of inbreeding, inbreeding co-efficient, path coefficient; Building of pedigree files; Statistical analysis in relation to genetic stock structure analysis with dominant and co-dominant markers; Type I and Type II markers, protein, mtDNA and nuclear DNA markers, EST markers.
Suggested Readings

1. An Introduction to Quantitative Genetics: 4th Ed. D.S. Falconer;
2. Population Genetics: C.C. Li;
3. Population Genetics in Animal Breeding: Pirchner;
5. A Primer in Population Genetics – Daniel Hartl
6. Population Genetics: Hartl and Clarke

Journals

1. Journal of Animal Breed and Genetics
2. Journal of Genetics
3. Journal of Heredity
4. Indian Journal of Genetics and Plant Breeding
5. Animal Genetics
6. Journal of Animal Science

Broad Research Areas

1. Estimation of gene and genotype frequencies using various population genetic tools (markers)
2. Estimation of effective population size, inbreeding accumulation rate in a breeding population
3. Constructing Family tree for a population
4. Genetic stock structure analysis
5. Genetic variability studies of species of commercial importance

FGB 503 QUANTITATIVE GENETICS 2+1

Objective

Understanding the concepts of quantitative genetics and its applications

Theory

Unit I

Quantitative genetics: scope and applications; Polygenes and major genes; Polygenic segregation and linkage.

Unit II

Quantitative and qualitative traits: mode of inheritance and continuous variation; Components of phenotypic value: population mean, genotypic value, average effect of gene and gene substitution.

Unit III

Breeding value: dominance and interaction deviations; Components of variation: additive and non-additive interaction; Biometrical relationship among relatives.

Unit IV

Genetic parameters: introduction, repeatability, heritability and genetic, phenotypic and environment correlations.
Unit V  Selection: effect on population structure, intensity of selection, response to selection, methods of selection; Genetic gain and correlated response; Utilisation of non-additive genetic variance.

Unit VI  Heterosis: theories and estimation; Maternal effects; Dihalele crossing; General and specific combining ability; Recurrent and reciprocal recurrent selection; Scale effects and their estimation; Progeny testing.

Practical  Properties of Variance, Covariance, Correlation and regression; ANOVA in genetic parameter estimation; Analysis of genetic variance; Estimation of heritability by half-sib, full-sib and mid-parent analyses; Repeatability and their accuracies; Estimation of genetic gain and their relative efficiencies; Procedures for estimating breeding values; Analysis of dihalele crossing.

2. Population Genetics: C.C. Li;  
3. Population Genetics in Animal Breeding: Pirchner;  
5. Quantitative genetics in Sheep Breeding --- Young and Turner  
6. Genetics and Analysis of Quantitative Traits: Lynch M, Walsh B.

Journals 1. Journal of Animal Breed and Genetics  
2. Journal of Genetics  
3. Journal of Heredity  
4. Indian Journal of Genetics and Plant Breeding  
5. Animal Genetics  
6. Journal of Animal Science

Broad Research Areas 1. Estimation of genetic parameters in species of commercial importance  
2. Estimation of repeatability and their accuracies  
3. Estimation of genetic gain

FGB 504  PRINCIPLES OF SELECTION AND SELECTION METHODS  2+1

Objective  Application of the genetic tools for genetic improvement of aquatic species

MFSc & PhD Syllabus: Fish Genetics and Breeding
Theory

Unit I  Selection: scope, application, role of genetics in fish selection and breeding; National and International scenario of selective breeding programs in fish.

Unit II Selection: basis of selection, genetic gain; Response to selection and factors affecting response; Accuracy of selection; Selection limits; Renewed selection gain; Bidirectional selection; Aids to selection; Methods of selection; QTL and MAS.

Unit III Construction of selection indices; Sire and dam evaluation; Realized heritability, repeatability and genetic correlations.

Unit IV Mating systems and genetic consequences; Inbreeding depression: causes and methods to overcome; Selection for threshold characters; Small stock and inbreeding effects; Out breeding: crossbreeding, utilization of heterotic effects.

Unit V Application of genetic parameter information in formulation of breeding plans; Stock improvement plans; Development of new strains/synthetic population; Crossbreeding and hybridization.

Unit VI Selection and mating designs for select traits: growth, disease resistance, color enhancement, fin characters; Application of markers in selection programs, status and their relevance.

Unit VII Development of breeding plans for different population sizes and environments; Trends in fish breeding research. Domestication and inadvertent selection; Genotype x Environment interaction and its role in fish/shellfish breeding.

Practical

Estimation of genetic parameters; and construction of selection indices; Estimation of genetic, phenotypic and environmental correlations; Analysis of GCA and SCA; Estimation of heterosis and inbreeding depression; Estimation of G X E interaction; Designing and conducting the challenge test for disease resistance.

Suggested Readings

1. An Introduction to Quantitative Genetics: 4th Ed. D. S. Falconer;
2. Population Genetics: C. C. Li;
3. Population Genetics in Animal Breeding: Pirchner;
5. Genetics and Analysis of Quantitative Traits: Michael Lynch and Bruce Walsh
6. Selection Indices and prediction of genetic merit in animal breeding: Cameron, N.D
7. Quantitative Genetics in sheep breeding – Young and Turner

Journals

1. Journal of Animal Breed and Genetics
2. Journal of Genetics
3. Journal of Heredity
4. Indian Journal of Genetics and Plant Breeding
5. Animal Genetics
6. Journal of Animal Science
7. Breeding Science
8. Annual Review of Genetics

**Broad Research Areas**

1. Developing breeding plans for different commercial fish and prawn species
2. Estimation of genetic parameters in species of commercial importance
3. Estimation of Genotype-Environment Interaction
4. Estimation of Heterosis and Inbreeding Depression in breeding population

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**M.F.Sc. (Fish Genetics and Breeding)**

**OPTIONAL COURSES**

**FGB 505 FISH BREEDING**

**2+1**

**Objective**
To learn the applications of genetic techniques for stock improvement

**Theory**

**Unit I** Historical development of fish breeding and domestication; Current status of aquaculture in world and India; Tagging and maintaining breeding records.

**Unit II** Performance: growth, disease resistance, productive and reproductive traits and their inheritance; Study of growth curves and their components; Influence of non-genetic factors on growth.

**Unit III** Endocrine control of reproduction; Synchronization of spawning.

**Unit IV** Effect of breeding programme on genetic diversity of farmed animals; Present status of breeding, cross breeding in aquaculture; Broodstock management; Inbreeding depression and heterosis in various economic characters; Role of Breeders’ associations in national breeding programs.

**Unit V** National breeding policy; Economic analyses of national breeding programs.

**Unit VI** Reproductive cycle, sex determination, age of maturity, hormone induced ovulation; Gonad developmental stages in fin/shellfish and levels of hormonal intervention; Seed quality and fish seed certification; Biosecurity.

**Practical**
Tagging methods; Construction of growth curves; Standardization of the performance records for genetic parameters estimations, Record keeping of stock; Breeding plan and
design of breeding program from successful case studies; Morphometric analysis; Practicals on synchronization of spawning.

Suggested Readings

1. Growth curves: Kshirsagar
2. Seed Production Technology: Thomas, P.C., Mahapatra
3. The Biology of Fish Growth: Weatherely, A.H. & Gill, H.S

Journals

1. Journal of Animal Breed and Genetics
2. Indian Journal of Genetics and Plant Breeding
3. Animal Genetics
4. Journal of Animal Science
5. Breeding Science
6. Annual Review of Genetics

Broad Research Areas

1. Construction of growth curves for different commercial fish and prawn species
2. Estimation of genetic and non-genetic parameters
3. Developing breeding plans for different commercial fish and prawn species
4. Cryopreservation of gametes of species of commercial importance
5. Ploidy induction in fishes
6. Production of mono sex population

FGB 506 FISH GENETIC RESOURCES AND CONSERVATION 2+1

Objective Application of genetic principle in conservation and management of aquatic resources

Theory

Unit I Fish genetic resources: Survey and distribution; Genetic diversity - importance, estimation and influencing factors.

Unit II Characterization and evaluation: taxonomical, biochemical and molecular tools; Threatened aquatic species of India and world.

Unit III Conservation and preservation of aquatic species: issues and strategies, endangered species as per the guidelines of IUCN; Breeding strategies of threatened species for restocking and live gene bank.

Unit IV Data bank and Gene bank: concepts, objectives, resources, uses; Institutes and Societies associated with conservation; Impact of inbreeding on genetic diversity and conservation; Evolutionary potential and heritability.
Unit V  Importance of mutation, migration and their interaction with selection in conservation; Application of molecular genetic tools for management of small population for conservation.

Unit VI  Genetics and management of wild and captive populations; Genetic management for reintroduction; *in-situ* and *ex-situ* conservation; Cryopreservation of sperm, eggs and embryos.

Unit VII  Effective population size and population structure; Factors threatening indigenous species; IPR issues and patenting of genetic resources; Regulations regarding introduction of exotic germplasm; Export import rules and regulations on conservation of aquatic genetic resources; Fish quarantine – status, procedures, scope and significance; Convention on Biodiversity and Biodiversity Authority of India.

Practical  Tagging methods for population; Estimation of gene and genotypic frequencies; Estimation of genetic diversity and relatedness using molecular information; Application of molecular genetic markers for estimation of effective population size, rate of inbreeding and genetic bottleneck; Analysis of genetic variance in population; Morphometric analysis of stocks; Milt quality analysis; Cryopreservation of milt.

Suggested Readings
1. Genetic conservation of salmonid fishes: Joseph G. Cloud and Gary H. Thorgaard
2. A Primer of Conservation Genetics: Richard Frankham
3. Primer of Population Genetics: Daniel L. Hartl
5. Introduction to Conservation Genetics: Richard Frankham

Journals
1. Animal Genetic Resource Information
2. Conservation Genetics
3. Conservation Biology
4. Biological Conservation

Broad Research Areas
1. Application of molecular genetic markers for estimation of effective population size, rate of inbreeding
2. Estimation of genetic diversity and relatedness using molecular information
3. Morphometric analysis of stocks
4. Milt quality analysis and Cryopreservation of milt
Objective  
Molecular genetic tools for selective breeding programs

Theory  
Unit I  Biochemical markers: Allozyme polymorphism and application in estimating population genetic parameters.
Unit II  Molecular markers: RAPD, RFLP, AFLP, EST, SNP, minisatellites and microsatellites and application in population genetic analysis and gene mapping.
Unit III  DNA sequence polymorphism and related software for alignment and analysis.
Unit IV  Molecular biology of Ig synthesis, genetic basis of antibody diversity: humoral B-cell immunoglobulins, T-cell receptors and MHC.

Practical  
Allozyme electrophoresis; RAPD, RFLP, AFLP, minisatellites and microsatellites- DNA electrophoresis; Interpretation of gels and data analysis using various software; Estimation of linkage disequilibrium using molecular genetic data; Antibody titre estimation.

Suggested Readings  

Journals  
1. Acta Cytologica
2. Advances in Genetics Incorporating Molecular Genetic Medicine
3. Indian Journal of Cytology and Genetics

Broad Research Areas  
1. Estimation of linkage disequilibrium using molecular genetic data
2. Application of molecular genetic markers for estimation of effective population size, rate of inbreeding
3. Estimation of genetic diversity and relatedness using molecular information
4. QTL Analysis and application in selective breeding
Objective
To understand the basic concepts of molecular genetics

Theory
Unit I  Gene structure of DNA, replication, Protein synthesis; Operon concept, genetics of mitochondria and plasmids, transposons and intervening sequences, minisatellites and macro satellites.

Unit II  Mutations: Molecular mechanism of spontaneous and induced mutations, site directed mutagenesis, recombination in bacteria, fungus and virus.

Unit III  Recombination: Molecular mechanism of genetic recombination, transduction, transformation and conjugation.

Unit IV  Genetic code, mechanism of translation and its control, post translation modification. Control of gene expression in prokaryotes and eukaryotes.

Practical  DNA isolation, Plasmid isolation, Gel electrophoresis and its type, AGE, PAGE, SDS-PAGE, PCR, Cloning

Suggested Readings

Journals
2. Molecular and Cellular Biology
3. Journal of Bio-chemistry and Molecular Biology
4. BMC Molecular Biology

Broad Research Areas
1. Estimation of linkage disequilibrium using molecular genetic data
2. Application of molecular genetic markers for estimation of effective population size, rate of inbreeding
3. Estimation of genetic diversity and relatedness using molecular information
4. QTL Analysis and application in selective breeding
**FGB 509 CYTOGENETICS** 1+1

**Objective**
To understand chromosome as the basic unit of heredity

**Theory**

Unit I: Introduction, historical background, importance, improved cytogenetic techniques.

Unit II: Chromosome theory of inheritance: chromosomal models and their ultra structure; Chromosomal movements and position effect.

Unit III: Sex determination and differentiation, sex chromatin and Lyon’s hypothesis; Chromosome numbers in fish and karyotyping.

Unit IV: Chromosomal aberrations: genetic and evolutionary implications; Chromosome banding techniques; FISH.

Unit V: Cytogenetics and evolution; Genotoxicity assays (single cell electrophoresis, MNT, SCE).

**Practical**
Preparation of chromosome spreads; Karyotyping; Banding techniques; MNT, SCE, Comet Assay.

**Suggested Readings**
1. Fish Cytogenetics: Pisano, E.
2. Fish Genetics and Biotechnology: W.S.Lakra;
3. Fish Genetics and Biotechnology - ICAR Publication (Eds. Ayyappan, Thumpy, Reddy, Krishna)

**Journals**
1. Cytogenetics
2. Molecular Cytogenetics
3. Cancer Genetics and Cytogenetics

**Broad Research Areas**
1. Chromosome mapping for different commercial fish and prawn species
2. Karyotyping and chromosome spread preparation for different commercial fish and prawn species
3. Chromosome banding
Objective
To learn the application of information technology for the fish genetics studies

Theory
Unit I Introduction to bioinformatics: history, definition, scope and applications; Fields related to bioinformatics.
Unit II Data base: mining tools, submission of DNA sequences; Sequence alignment and database searching, similarity search, FASTA, BLAST.
Unit III Information networks: internet; Genbank sequence database, EBI-net; NCBI, Genomenet.
Unit IV Genomics: genome diagnostics, genome projects, genome analysis.
Unit V Proteomics: protein information resources, primary and secondary protein data bases, analysis packages, predictive methods, ESTs.
Unit VI Phylogenetic analysis; Comparative genome analysis; Microarray bioinformatics.

Practical
Internet search: retrieving information from different data base like NCBI, protein information sources; Preparation of data base; Use of genome analysis packages: genetics data base; Searching by similarity; Phylogenetic analysis; Accessing and submission to genebanks; BLAST, sequence alignments, comparisons.

Suggested Readings
1. Discovering Genomics, Proteomics, and Bioinformatics: Malcolm Campbell, A.
2. Introduction to Bioinformatics: Arthur M. Lesk
3. Bioinformatics Basics: Applications in Biological Sciences and Medicine by Rashidi, H.H. and Buehler, L.K.
4. Introduction to Bioinformatics, Attwood, T.K. and Parry-Smith, D.J.
5. Bioinformatics: Sequence and Genome Analysis, David W. Mount
   Stuart M. Brown

Journals
1. In Silico Biology
2. Bioinformatics
3. BMC Bioinformatics
4. Briefings in Bioinformatics
5. Briefings in Functional Genomics and Proteomics
FGB 511  COMPUTER APPLICATIONS IN FISH GENETICS  1+1

Objective  To comprehend the use of software packages for genetic data analyses

Theory  
Unit I  File Transfer Protocols; Work stations; Application of spreadsheets in maintaining fish breeding records; Fish breeding data bases.

Unit II  Introduction to various computer packages used in genetic analyses: SAS, AsREML, PEST, SelAction; Hendersons’ models in breeding experiments.

Unit III  Software for molecular genetics data analysis; Bioinformatics; Bioinformatic applications and tools in fish genetics and breeding; 'R' statistical package.

Practical  Data input, import, export, modification; Spread sheet in breeding data management; Use of ML and Reml packages for various component estimation; Estimation of genetic parameters using various statistical packages like SAS, AsREML, PEST, SelAction; Molecular data analysis using softwares like GENEPOP.

Suggested Readings  
1. SAS System for Mixed for Mixed Models, Littell, R.C. and others
2. Little SAS Book
6. AsReml Cook Book
7. Genetics and Analysis of Quantitative Traits : Michael Lynch and Bruce Walsh

Journals  
1. Journal of Statistical Software
2. Journal of Computational and Graphical Statistics
Broad Research Areas

1. Estimation of genetic parameters using various statistical packages like SAS, AsREML, PEST
2. Molecular data analysis using softwares like GENEPOP

FGB 512 CELL AND TISSUE CULTURE 1+1

Objective
Understanding the basic principles and techniques of cell and tissue culture.

Theory

Unit I Introduction: Structure and Organization of animal cell; Equipments and materials for animal cell culture technology.

Unit II Cell lines and media: Primary and established cell line cultures; media supplements – their metabolic functions; serum & protein free defined media and their application.

Unit III Cell culture: Basic techniques of cell culture in vitro; development of primary cultures, cell separation, maintenance of cell lines; biology of cultured cells, transformation and differentiation of cell cultures.

Unit IV Characterization of cell lines: measurement of viability and cytotoxicity assays; measuring parameters of growth; karyotyping, isozyme assays, cryopreservation, assessment of contaminants.

Unit V Cell cloning: Micromanipulation, cell transformation, application of fish cell culture, scaling-up of cell culture.

Unit VI Cell hybridization: Somatic cell fusion, hybridoma technology, Production and Application of monoclonal antibodies

Practical Principles of sterile techniques and cell propagation; Preparation of different cell culture media; Primary cell culture techniques; Establishing cell lines: isolation, characterization identification of cell lines; Pure culture techniques; Maintenance and preservation of cell lines; Propagation of cells in suspension cultures; Hybridoma technology: strategy and techniques; Production of monoclonal antibodies.

Suggested Readings
2. General Techniques of Cell Culture: Harrison and Rae

Journals
1. Journal of Tissue Culture Methods

Broad Research Areas

1. Establishing cell lines
Ph.D. (Fish Genetics and Breeding) SYLLABUS

MAJOR - CORE COURSES

FGB 601 ADVANCES IN FISH BREEDING  2+1

Objective  To evaluate the recent advances and development of breeding plans.

Theory

Unit I  Broodstock management; Controlled breeding and reproduction in commercially important fish and shellfish species.

Unit II  Endocrine control of reproduction; Artificial insemination in shrimp; Synchronisation of spawning; Cryopreservation of gametes.

Unit III  Estimation of heritability and repeatability; Phenotypic, genetic and environmental correlations; Tagging and maintaining breeding records; Growth curves and their components.

Unit IV  Influence of non-genetic factors on growth; Factors influencing production and reproductive traits; Crossbreeding and hybridization; Threshold characters and their selection procedure.

Unit V  Breeding plans to exploit additive and non-additive genetic variation; Maternal influence and its estimation, genetic mechanisms in adaptation, measurement and adaptability indices; G x E interaction.

Unit VI  Consequences of inbreeding and management of genetic variation in fish breeding program.

Practical  Heritability estimation; Correlation between different traits; Selection and genetic gains; Inbreeding; Preservation of gametes; Synchronization of spawning; The focus will be on critical review of contemporary applied breeding programs and journal articles - students are also expected to prepare a term paper for submission at the end of the semester.

Suggested Readings

1. Growth curves : Kshirsagar
2. Seed Production Technology: Thomas, P.C., Mahapatra
3. An Introduction to Quantitative Genetics: 4th Ed. D.S.Falconer;
4. Population Genetics: C.C.Li;
5. Population Genetics in Animal Breeding : Pirchner;
Journals

1. Journal of Animal Breed and Genetics
2. Indian Journal of Genetics and Plant Breeding
3. Animal Genetics
4. Journal of Animal Science
5. Breeding Science
6. Annual Review of Genetics

Broad Research Areas

1. Construction of growth curves for different commercial fish and prawn species
2. Estimation of genetic and non-genetic parameters
3. Developing breeding plans for different commercial fish and prawn species
4. Cryopreservation of gametes of species of commercial importance
5. Ploidy induction in fishes
6. Production of mono sex population

FGB 602  SELECTION INDEX METHODOLOGIES  2+1

Objective To evaluate the efficiency of different selection methods.

Theory

Unit I Introduction: Past and present status of fish breeding.

Unit II Strain comparison; Factors affecting the rate of genetic improvement; Performance testing.

Unit III Correction and standardization of animal breeding data; Simultaneous prediction of breeding values for several animals; Recurrent and Recurrent Reciprocal Selection.

Unit IV Prediction of breeding values and environmental effects; LS, BLUP, REML methods, Multivariate Breeding Value Prediction.

Unit V Selection based on gene of known large effect: QTL and MAS; Breeding values for binary traits; Selection and breeding for disease resistance and survival analysis; Partial diallele analysis; Selection for single trait and multiple traits.
Practical

Diallele crossing; Estimation of breeding values; Construction of selection index; Least squares and BLUP methods for estimation of genetic and non genetic parameters; Application of various computer software for genetic analyses: SAS, AsREML, PEST, and SelAction; Estimation of genetic parameter, heritability, building of pedigree information.

Suggested Readings

1. An Introduction to Quantitative Genetics: 4th Ed. D. S. Falconer;
2. Population Genetics: C. C. Li;
3. Population Genetics in Animal Breeding: Pirchner;
5. Genetics and Analysis of Quantitative Traits: Michael Lynch and Bruce Walsh
6. Selection Indices and prediction of genetic merit in animal breeding: Cameron, N.D
7. Quantitative Genetics in sheep breeding – Young and Turner

Journals

1. Journal of Animal Breed and Genetics
2. Journal of Genetics
3. Journal of Heredity
4. Indian Journal of Genetics and Plant Breeding
5. Animal Genetics
6. Journal of Animal Science
7. Breeding Science
8. Annual Review of Genetics

Broad Research Areas

1. Developing breeding plans for different commercial fish and prawn species
2. Estimation of genetic parameters in species of commercial importance
3. Estimation of Genotype-Environment Interaction
4. Estimation of Heterosis and Inbreeding Depression in breeding population

FGB 603 APPLICATION OF GENETICS IN COMMERCIAL AQUACULTURE 2+1

Objective

To review of genetic improvement program to critically evaluate the impact on commercial aquaculture.

Theory

Unit I Evaluation of International genetic improvement programs like GIFT Tilapia, Norwegian

**Practical**
Developing the protocols for evaluating the various impacts.

**Suggested Readings**
1. Genetic bases of fish selection: V.S. Kirpichnikov;
2. Genetics and Fish Breeding: C.E. Purdom;
3. Practical Genetics for Aquaculture: C. Greglutz
4. Genetics and Analysis of Quantitative Traits: Lynch M, Walsh B.

**Journals**
1. Journal of Animal Breed and Genetics
2. Journal of Genetics
3. Journal of Heredity
4. Indian Journal of Genetics and Plant Breeding
5. Animal Genetics
6. Journal of Animal Science
7. Breeding Science
8. Annual Review of Genetics

**Broad Research Areas**
1. Socio-economic impact studies for genetically improved varieties
2. Evaluation of International genetic improvement programs

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**Ph.D. (Fish Genetics and Breeding)**

**OPTIONAL COURSES**

**FGB 604**
**RESEARCH METHODOLOGY IN FISH GENETICS**

**Objective**
Integration of the methodologies under various genetic approaches.

**Theory**
- Unit I **NOT AVAILABLE**
- Unit II **NOT AVAILABLE**
- Unit III **NOT AVAILABLE**
- Unit IV **NOT AVAILABLE**
Objective
To critically evaluate the advances in cytogenetics and their applications in genetic programs.

Theory

Unit I Chromosomal theory of sex determination, sex differentiation; Diploid number of chromosome in finfish and shellfish; Karyotyping.

Unit II Chromosomal aberrations: inherited and induced, structural and numerical; *In-vitro* techniques for chromosome handling.

Unit III Chromosome banding: Advanced chromosome banding including Restriction Enzyme banding, fluorescent banding, CMAS3 staining, replication banding; FISH.

Unit IV Genotoxicity assays including Sister chromatid exchanges, MNT, commet assay.

Unit V Cytogenetics and fish evolution; Cytoplasmic inheritance; Cytogenetic application in fish breeding programmes.

Practical Preparation of chromosome spreads using *in-vivo* and *in-vitro* methods; Karyotyping; Banding methods: G, C NOR, Restriction Enzyme banding; Fluorescent banding, CMAS3 staining, replication banding; Screening the brooders for cytogenetic defects.

Suggested Readings
1. Fish Cytogenetics: Pisano, E.
2. Fish Genetics and Biotechnology: W.S.Lakra;
5. Working with Animal Chromosomes By H. C. McGregor. John Wiley and Sons

Journals
1. Cytogenetics
2. Molecular Cytogenetics
3. Cancer Genetics and Cytogenetics
1. Chromosome mapping for different commercial fish and prawn species
2. Karyotyping and chromosome spread preparation for different commercial fish and prawn species
3. Chromosome banding

FGB 606  MOLECULAR BREEDING  2+1

Objective
To evaluate the advances in molecular breeding and their incorporation in genetic improvement programs.

Theory
Unit I  Exploitation of non additive genetic variance; Breeding for disease resistance; Survival analysis.
Unit II  Application of markers in fish breeding; Identification of QTLs and MAS.
Unit III  Cryopreservation of gametes and its applications.
Unit IV  Chromosome and gene manipulation; Cross breeding and hybridization; Maintenance of variation; Radiation hazards.
Unit V  Genetic evaluation of exotics and quarantine procedures; Patenting methods, IPR issues related to fish genetic innovations.

Practical
Identification of QTLs; Gene mapping; molecular identification of stock; Radiation hazards and effect on genetic components, pedigree assigning using molecular data, estimation of genetic parameters using molecular data.

Suggested Readings
1. Quantitative Trait Loci Analysis in Animals: Weller, J.I.
2. Genetics and Analysis of Quantitative Traits: Lynch, M. and Walsh, B.

Journals
1. Journal of Animal Breed and Genetics
2. Journal of Genetics
3. Journal of Heredity
4. Indian Journal of Genetics and Plant Breeding
5. Animal Genetics
6. Journal of Animal Science

Broad
1. Molecular identification of stock
Research Areas

2. Pedigree assigning using molecular data
3. Estimation of genetic parameters using molecular data

FGB 607  TRANSGENICS PRODUCTION AND GMOs  1+1

Objective
Evaluate the current status in development of transgenics and their potential commercialisation.

Theory

Unit I  Principles of transgenic technology and transgenic production, Its application to fisheries; Risk assessment; GMOs and biosafety regulations, gene therapy, designer ornamental fish strains; Biotechnological interventions in fish breeding;

Unit II  Ethical Issues in GMOs: Cartigan protocol, National regulations on GMOs, Impact assessment of GMOs, transgenic containment.

Practical
Gene transfer experiments; Northern blotting, Southern blotting for integration and expression of transgene; Demonstration of the electroporation, microinjection, expression of the marker genes.

Suggested Readings
1. Transgenic Animal Technology: A Laboratory Handbook: Carl A. Pinkert

Journals
1. Journal of Animal Breed and Genetics
2. Journal of Genetics
3. Journal of Heredity
4. Indian Journal of Genetics and Plant Breeding
5. Animal Genetics
6. Journal of Animal Science

Broad Research Areas
1. Impact assessment studies of GMOs
Objective
To learn the application of linear models in fish breeding data.

Theory
Unit I Matrix operations: determinants, inverse of matrix, linear equations, the matrix algebra of regression analysis;
Unit II Analysis of non-orthogonal and multivariate data;
Unit III Linear models: fixed effects, random effects; Mixed models: their application in estimation of genetic parameters; Model building and simulations.

Practical
Matrix operation, matrix inversion, matrix algebra of regression analysis; Analysis of non orthogonal and multivariate data; Least Square analysis in the one way classification; One way classification with regression and covariance; Two way classification with and without interactions; Multiple and nested classification; Maximum likelihood estimation of genetic parameters under linear and non linear models; Use of various statistical packages for genetic parameter estimations: SAS, REML, PEST, SelAction.

Suggested Readings
1. SAS System for Mixed for Mixed Models, Littell, R.C. and others
2. Genetic Analysis of Complex Traits Using SAS, Ed. Saxton, A.M.
3. AsReml Cook Book
4. Genetics and Analysis of Quantitative Traits : Michael Lynch and Bruce Walsh

Journals
1. Journal of Statistical Software
2. Journal of Computational and Graphical Statistics

Broad Research Areas
1. Estimation of genetic and non-genetic parameters using various statistical packages like SAS, AsREML, PEST