Department of Genetics and Plant Breeding
Ch. Charan Singh University, Meerut

Syllabus for M. Sc. (Ag.) Genetics and Plant Breeding as per CBCS w.e.f. 2016-17

Course Type	Name of Course	Course Code	Credits L+P+T	Maximum Marks			
				Int.	Ext.	Prac.*	Total
SEMESTER I							
Compulsory Core	General Genetics		4+1+0	40	40	20	100
	Cytology & Cytogenetics		4+1+0	40	40	20	100
	Principles and Methods of Plant Breeding		4+1+0	40	40	20	100
	Sub-total of credits		**15**				
Elective Core	Statistical Methods		4+1+0	40	40	20	100
	Sub-total of credits		**5**				
Thesis Work	Component - I		**8**				
	Total		**28**				**400**
SEMESTER II							
Compulsory Core	Plant Genetic Resources: Conservation and Sustainable Use		4+1+0	40	40	20	100
	Breeding for Biotic Stress		4+1+0	40	40	20	100
	Molecular Genetics		4+1+0	40	40	20	100
	Sub-total of credits		**15**				
Elective Core	Computer applications and Bioinformatics		4+1+0	40	40	20	100
	Sub-total of credits		**5**				
Open Elective§	Plant Physiology		4+0+0				Qualifying
Thesis Work	Component - II		**12**				
	Total		**32**				**400**
SEMESTER III							
Compulsory Core	Breeding for Abiotic Stress and Quality		4+1+0	40	40	20	100
	Population and Biometrical Genetics		4+1+0	40	40	20	100
	Heterosis and its Exploitation		4+1+0	40	40	20	100
	Sub-total of credits		**15**				
Elective Core	Plant Biotechnology		4+1+0	40	40	20	100
	Sub-total of credits		**5**				
Open Elective§	Global Food and Nutritional Security		4+0+0				Qualifying
Thesis Work	Component - III		**12**				

	Total		**32**				**400**
SEMESTER IV							
Compulsory Core	Advanced Genetics		4+1+0	40	40	20	100
	Molecular Basis of Quantitative Inheritance		4+1+0	40	40	20	100
	Principles and Practices of Seed Production		4+1+0	40	40	20	100
	Sub-total of credits		**15**				
Elective Core	Genomics, Transcriptomics and Proteomics		4+1+0	40	40	20	100
	Sub-total of credits		**5**				
Thesis Work	Component - III		8				
	Total		**28**				**400**
M. Sc. (Ag.) Thesis							
M. Sc. (Ag.) Thesis	Component-I (C_1): Periodic progress and progress reports (15%)						
	Component-II (C_2): Results of work and draft report (15%)						
	Component-III (C_3): Final viva-voce and evaluation (70%) (a) The report evaluation (40%) (b) Viva-voce examination (30%)						
	Total credits in M.Sc. Ag. Thesis		**40**[#]				Satisfactory
	Grand Total of credits and maximum marks in whole M.Sc. Ag. program		**120**				**1600**

[*]In each semester, there shall be one joint external practical examination carrying 80 marks based on all the four courses (20+20+20+20 marks) of compulsory and elective core.

[#]Minimum 36 credits are required for M. Sc. (Ag.) thesis.

[§]Non credit course (qualifying)

☞Pattern of examination, passing marks, determination of CGPA/division shall be as per rules applicable in faculties of Sciences and Arts in university campus.

☞There shall be an advisory board consisting up to 3 members (major and minor) for guiding students for M. Sc. (Ag.) thesis from the department and minor can be from outside of the department/university.

Semester I

General Genetics

Credits: 4+1+0
Teaching hours: 50

1. **Introduction:** History of genetics, its scope and significance, brief idea of Mendel's laws and physical basis of heredity (chromosome theory of inheritance), forward vs. reverse genetics. 2

2. **Modification of F_2 ratios:** Epistasis (non-allelic interactions), segregation distortion and selfish genes; penetrance and expressivity; modifiers and suppressors; pleiotropic genes. 4

3. **Linkage and crossing over:** Coupling and repulsion hypothesis; theories of crossing over; three point test cross (interference and coincidence; calculation of recombination frequencies from F_2 data; brief idea about mapping function; cytological basis of crossing over (experiments of Stern in *Drosophila* and that of McClintock in corn). 4

4. **Multiple alleles:** Concept of multiple alleles; self incompatibility alleles in *Nicotiana* and *Brassica;* coat colour in rodents; blood groups in humans, antigen-antibody interaction in inheritance of A, B, AB and O blood groups; H – antigens, MNS system, Rh factor. Epistasis and multiple allelism (e. g. Bombay blood groups). 4

5. **Quantitative inheritance**: Multiple factor hypothesis (a brief introduction); concept of gene effects (additive, dominance, over–dominance and epistasis); polygenes and quantitiave trait loci (QTL). 2

6. **Sex linked inheritance**: Sex linked**,** sex limited and sex influenced traits with suitable exmamples. 2

7. **Sex determination and differentiation**: Theories of sex determination -- chromosome theory and genic balance theory of sex determination, sex determination in dioecious plants {*Marchantia, Ceratopteris, Silene (Melandrium), Humulus, Coccinia, Rumex, Papaya*}, mouse and in man; genetic basis of sex differentiation (genes located on sex chromosomes and autosomes), single gene control of sex. Hormonal control of sex, sex reversal and gynandromorphs, human sex anomalies (Klinefelter's syndrome and Turner's syndrome); brief idea of dosage compensation and Lyon's hypothesis. 8

8. **Extrachromosomal inheritance**: Criteria for extra chromosomal inheritance; plastid inheritance in *Mirabilis*, iojap in corn, Kappa particles in *Paramecium*, coiling in snails, brief idea of mitochondrial (male sterility in plants) and .chloroplast genetics, paternal inheritance. 6

9. **Mutations and mutagenic agents**: Brief history of mutations; types of mutations; rate and frequencies of mutations; physical and chemical mutagens and deletogens; detection of mutations in *Drosophila* (ClB method, Muller–5 method, attached X method), detection of mutations in plants and their practical application in crop improvement. (molecular basis of mutations are included in another course). 8

10. **Biochemical genetics**: Inborn errors of metabolism in man; eye transplantation in *Drosophila;* biochemical mutations in *Neurospora;* biosynthetic pathways and biochemical mutations. 4

11. **Fine structure of gene**: Classical and modern gene concepts; pseudoallelism, position effect; intragenic crossing over and complementation (cistron, recon, muton), Benzer's work on r_{II} locus in T_4 phage. 6

12. **Epigenetics**: An Introduction to paramutation; DNA methylation and histone modification; genome imprinting (IGF_2 in mammals) 'Solid gold' or Callipyge in sheep; epigenetics in *Arabidopsis* and *Linaria*; histone code..
2

Suggested Readings:

1. Gupta P K (2009). Genetics, 4/e. Rastogi Publications, Meerut.
2. Gupta P K (2007). Genetics:Classical to modern. Rastogi Publications, Meerut.
3. Griffith et *al* (2008). An introduction to Genetic Analysis. Freeman & Co.
4. Hartl DL and Jones EW (1997). Genetics: Principles and Analysis 4th Ed. Jones & Bartlett Publishers, Inc
5. Hartwell L *et al* (2000). Genetics: From genes to genomics. McGraw Hill, New Delhi.
6. Lewin B. (2007). Genes IX. Wiley Eastern Ltd., New Delhi.
7. Pierce, B. (2005). Genetics: A conceptual Approach 2nd Ed. WH Freeman
8. Snustad D P , Simmons NJ and Jenkins JB (2003). Principles of Genetics. John Wiely & Sons, New York.
9. Strickberger, N.W. (1985). Genetics 3rd Ed. Macmillan Co. New York.

Cytology and Cytogenetics

Credits: 4+1+0
Teaching hours: 50

1. **Historical perspectives.** 2

2. **Nucleus and chromosome territories:** A and B chromosomes, NOR, non-random distribution of chromosomes during interphase, Rabl configurations and Bouquet. 2

3. **Cell division:** Cell cycle (genetics, biochemistry and cell cycle mutants), differences between mitosis and meiosis; mechanism of chromosome movement; reduction division and equational division; double reduction. 4

4. **Chromosome pairing:** Synaptonemal complex, somatic association, Rabl configurations and its role in pairing, biochemical basis of chromosome pairing. 4

5. **Chromosome banding techniques for identification of chromosomes:** Q bands, C and N bands, G bands, R bands; Chromatin remodeling. 2

6. **Duplications and deficiencies**: Classification, methods of production, meiotic pairing, phenotypic effects and breeding behavior. 2

7. **Translocations**: Classification, methods of production, identification, meiotic pairing (alternate and adjacent disjunction), crossing over in interstitial region, breeding behavior of translocation heterozygote, role in evolution (balanced lethals- *Oenothera* cytogenetics), A-B translocations. 8

8. **Inversions**: Classification (paracentric and pericentric inversions), methods of production, identification, meiotic pairing and crossing over in different regions, anaphase I and anaphase II configurations in paracentric inversions, breeding behavior of inversion heterozygote, role in evolution. 6

9. **Haploidy**: Classification (monoploids, polyhaploids and aneuhaploids), methods of production (anther culture and chromosome elimination), identification, androgenic and gynogenetic, and parthenogenic haploids, meiotic pairing, utility (hybrid sorting and DH breeding). 4

10. **Polyploidy**: Classification (autopolyploids, allopolyploids), methods of production, cytological and genetic methods for identification, polyploid genetics (chromosome and chromatid segregation), meiotic pairing (autosyndesis and allosyndesis), diploidizing system (*Ph1* locus) and role in evolution, utility in crop improvement, segmental poluploidy, synthetic polyploids, brief idea of ancient polyploidy. 6

11. **Trisomics and tetrasomics (Hyperploids)**: Classification (primary, secondary and tertiary trisomics), methods of production, identification, meiotic pairing, breeding behavior of trisomics, trisomic and tetrasomic ratios, utility in chromosome mapping. 4

12. Monosomics and nullisomics (Hypoploids): Methods of production (particularly in wheat), identification, meiotic behavior; breeding behavior of monosomics, monosomic analysis (monogenic characters only); alien addition/substitution lines. 2

13. Physical mapping of genes on chromosomes: *In situ* hybridization with DNA probes (FISH, McFISH, GISH, fibre fish); deletion mapping 2

14. Apomixis: Cytogenetic basis of apomixis, meiotic behavior in apomicts, autogamy and pseudogamy, agamospermy (apospory and diplospory) and other modes of apomixis. 4

Suggested Readings:

1. Burnham, C.R. (1962). Discussions in Cytogenetics: Burgers, Minneapolis.
2. Fukui K and Nakayama S (eds.) (1996). Plant Chromosomes-Laboratory Methods. CRC Press, London
3. Gupta, P.K. (1999). Cytogenetics. Rastogi & Co., Meerut.
4. Gupta, P.K. and Tsuchiya, T. 1991. Chromosome Engineering in Plants: Parts A & B, Elsevier Publishers, the Netherlands.
5. Gupta PK, Singh SP, Balyan HS, Sharma PC and Ramesh B (1998). Genetics and Biotechnology in Crop Improvement. Rastogi Publications, Meerut
6. Hawes C and Satiat-Jennemaitre (eds.). (2001). Plant Cell Biology 2nd Ed. Oxford University Press, New York
7. Khush GS (1973). Cytogenetics of Aneuploids. Academic Press, New York
8. Singh RJ (2003). Plant Cytogenetics (Second Edition). CRC Press, Taylor & Frances group.
9. Singh RJ and Prem P. Jauhar (Eds.) (2005). Genetic Resources, Chromosome Engineering, and Crop Improvement: Grain Legumes, Volume I. CRC Press, Taylor & Frances group
10. Swaminathan, M.S., Gupta, P.K. and Sinha, U. (1983). Cytogenetics of Crop Plants. Macmillan India, New Delhi.
11. Swanson, C.P., Merz, T. and Young, W.J. (1982). Cytogenetics. Prentice-Hall of India (Pvt.) Ltd., New Delhi.
12. Sybenga, J. (1972). General Cytogenetics. North-Holland publishing Co. Amsterdam.
13. Sybenga, J. (1992). Cytogenetics in Plant Breeding. Springer-verlag, Berlin.

Principles and Methods of Plant Breeding

Credits: 4+1+0
Teaching hours: 50

1. **Historical perspectives**: Past progress and future needs, green revolution, evergreen revolution. 2

2. **Mating Systems**: Self-fertilization, full sib mating, half sib mating, back crossing; inbreeding and backcrossing; random mating, assortative and disassortative matings, sister line crosses, convergent crosses, complex crosses, diallel selective mating, mating designs for components of variation. 6

3. **Genetic basis of breeding self pollinated crops**: selection; pure line theory and its genetic basis; sources of genetic variation, genetic consequences of hybridization (segregation and recombination of genes); composition of populations derived from hybrids; role of genotype and environment in continuous variation; heritability; genetic advance under selection. 10

4. **Breeding methods for self-pollinated crops:** A brief outline of the following: pure line and mass selection; pedigree method and its modification, bulk population method and its modifications. Backcross method; testing and evaluation of pure lines, hybrid breeding. 10

5. **Genetic basis of breeding cross pollinated crops:** Genetic basis of self incompatibility and male sterility and their use in hybrid seed production; genetic basis of inbreeding depression and heterosis; exploitation and fixation of heterosis; genetic basic of population improvement. 10

6. **Breeding methods for cross-pollinated crops:** selection, recurrent selection; development of hybrids, synthetics and composites. 4

7. **Mutations and polyploidy breeding:** Mutation breeding, distant hybridization and polyploid breeding including analytical breeding, mutant variety data (MVD)-IAEA. 4

8. **Breeding methods for vegetatively propagated crops**: Somatic mutations, examples of sugarcane and potato crops.

9. **Pre-breeding and genetic enhancement**: Wide hybridization and alien gene transfer. 2

10. **Crop varieties**: Identification, release and notification of crop varieties, institutions involved in release of varieties. 2

Suggested Readings:

1. Allard, R.W. (1960). Principles of Plant Breeding. John Wiley, New York
2. Chopra, V.L. (2000). Plant Breeding: Theory and Practice 2nd Ed. Oxford & IBH, New Delhi.
3. Frey, K. J. (1966). Plant Breeding. The Iowa State University Press, Ames.
4. Frey, K. J. (1982). Plant Breeding II. Kalyani Publishers, New Delhi.

5. Welsh, J. R. (1981). Fundamentals of Plant Genetics and Breeding. John Wiley and Sons, New York.
6. Poehlman, J.M. (1987). Breeding Field Crops, 3rd Ed. AVI Publishing Co. Inc., Westport, Connecticut
7. Poehlman J. M. and Sleper D. A. (1995). Breeding Field Crops, 4th Ed. Panima Publishing Corporation, New Delhi
8. Roy D. Analysis and Exploitation of Variation. Narosa Publishing, New Delhi
9. Simmonds, N.W. (1979). Principles of Crop Improvement. Longman Groups Ltd. London.
10. Singh B. D. (2007). Plant Breeding. Kalyani Publishers. Ludhiana.

Statistical Methods

Credits: 4+1+0
Teaching hours: 50

1. **Presentation of Data**: Frequency distributions; graphical presentation of data by histogram, frequency polygon, frequency curve and cumulative frequency curves. 6

2. **Measures of Locations and Dispersion**: Mean, median, mode and their simple properties (with-out derivation) and calculation of median by graphs; range, mean deviation, standard deviation, standard error, coefficient of variation. 6

3. **Probability and Distributions**: Random distributions; events exhaustive, mutually exclusive and equally likely; definition of probability (with simple exercises); definitions of binomial, Poisson and normal distributions; and simple properties of the above distributions (without derivation). 4

4. **Correlation and Regression**: Bivariate data-simple correlation and regression coefficients and their relation; Spearman rank correlation; limits of correlation coefficient; effect of change of origin and scale on correlation coefficient; linear regression and equations of line of regression; association and independence of attributes. 8

5. **Sampling**: Concept of population and sample; random samples; methods of taking a simple random sample. 4

6. **Tests of significance**: Sampling distribution of mean and standard error; z and t-test (equality of means; paired and unpaired t-test); t-test for comparison of means when variances of two populations differ; Chi- square test for goodness of fit; independence of attributes, and homogeneity of samples; interrelation between t-test and F-Test 12

7. **Experimental Designs:** Principles of experimental designs; completely randomized, randomized complete block design (missing plot value in RBD); latin square designs; augmented block design; simple factorial experiments (mathematical derivations not required); analysis of variance (ANOVA) and its use including estimation of LSD (CD) 10

Suggested Readings

1. Goulden, C.H. (1952). Methods of Statistical Analysis, 2/e, John Wiley, New York.
2. Hoshmand A. Reza 1988. Statistical Methods for Agricultural Sciences. Timber Press, Portland, Oregan, USA.
3. Kempthorne, O. (1957). An Introduction to Genetic Statistics, John Willey, New York.
4. Kempton RA and Fox PN (1997). Statistical Methods for Plant Variety Evaluation. Chapman and Hall
5. Panse, V.C. and Sukhatme, P.V. (1967). Statistical Methods for Agricultural Workers, I.C.A.R., New Delhi.
6. Snedecor, G.W. and Cochran, W.G. (1980). Statistical Methods, 7/e. Iowa State Univ. Press, Ames, Iowa.
7. Steel, R.G.D. and Torrie , H.H. (1960). Principles and Procedures of Statistics. McGraw- Hill, New York.
8. Gomez, AG and Gomez, AA (1994). Statistical Procedures for Agricultural Research, 2/e. John Wiley & Sons, New York.

Semester II

Plant Genetic Resources: Conservation and Sustainable Use

Credits: 4+1+0
Teaching hours: 50

1. **Centres of diversity and centres of origin:** Brief account of domestication of important crop plants (wheat, maize, rice, potato, sorghum and brassica) and gene pools. 2

2. **A brief idea of modern system of classification** (angiosperm phylogeny groups). 2

3. **Biodiversity vs. genetic resources:** Definition and explanation, alpha vs. beta biodiversity and methods of their study; present levels of biodiversity and rate of loss of biodiversity; causes for the loss of biodiversity; uses of biodiversity; extent of biodiversity in plants; exploration and germplasm collection, introduction and exchange of PGR. 8

4. **Direct and indirect uses of plant genetic resources for human welfare**: In plant breeding and agriculture, pharmaceuticals and in maintenance of ecosystem; Red Data books and endangered plant species. 4

5. **Plant genetic resources**: Different kinds of PGR- basic, derived and molecular; core collections; principles of germplasm characterization, DNA fingerprinting and plant bar codes; germplasm evaluation, maintenance and regeneration; plant quarantine aspects-sanitary and phytosanitary systems (SPS). 6

6. **Techniques for conservation of plant germplasm**: *In situ* and *Ex-situ* methods of conservation; cryopreservation of genetic materials; gene banks and cryobanks. 4

7. **Biodiversity International (IPGRI) and NBPGR:** Their role in conservation of PGR. 2

8. **Future harvest centers** (formerly IARCs) - a brief idea. 4

9. **CBD and sustainable use of biodiversity**. Gene treaty; Cartagena protocol; harmonization of international and national treaties. 2

10. **Role of FAO/CGIAR system for access to genetic resources**: ITPGRFA (International treaty on plant genetic resources for food and agriculture) and global system of PGR; FAO's commission on PGR (CPGR); International code of conduct for PGR collection and transfer; multilateral system for access to PGR. 6

11. **Biodiversity prospecting for agriculture and pharmaceuticals.** 2

12. **IPRs in plant breeding:** UPOV, plant breeders rights (PBRs); essentially derived varieties and farmers rights (FRs); protection of plant varieties and farmers rights act (PPV & FRA) 2001; intellectual property rights- patents, copyrights, trademarks; GATT and TRIPs, patents for higher plants; terminator and traitor techniques (v-GURT and t-GURT); biodiversity act 2002; geographical indications act 1999; amendments to patent act 1970 8

Suggested Readings

1. Engelmann F and Takagi H (eds). (2000). Cryopreservation of tropical germplasm. IPGRI, Rome
2. CGIAR Annual Reports. (http://www.cgir.org)
3. Swaminathan MS (1996). Biodeversity. Konark Publications, New Delhi
4. Swaminathan MS (1996). Agrobiodiversity and Farmers Rights. Konark Pub, New Delhi
5. Maxsted N, Ford-Lloyd BV and Hawkes JJ (eds) (1997). Plant Genetic Conservation. Chapman and Hall, London
6. Indian Framing Vol. 43 (7), October 1993
7. Negi SS (2003). Biodiversity and its Conservation in India, 2/e. Indus Books, New Delhi
8. Anonymous (1995). Encylopedia of Environmental Biology Vol. Academic Press
9. Rao RR (1994). Biodiversity In India. Bishen Singh Mahendra Pal Singh, New Delhi
10. Paroda RS and Arora RK (eds) (1991). Plant Genetic Resources: Conservation and Management. IPPGR, Rome
11. Swaminathan MS and Jana S (eds) (1992). Biodiversity- Implications for Global Food Security. McMillan India, New Delhi
12. Red Data Books Vols. 1 to 4. Botanical Survey of India, Dehradun
13. Benson EE (2003). Plant Conservation Biotechnology. Agrosciences, New Delhi
14. Joshi PC (2004). Biodiversity and Conservation. Agrosciences, New Delhi
15. Gaston KJ (2004). Biodiversity: An Introduction, 2/e.. Agrosciences, New Delhi
16. Zoological Survey of India. Environmental Awareness and Wild Life Conservation. Atlas Books, New Delhi
17. Lewin SA (2000). Encyclopedia of Biodiversity Vols. 1 to 5. Atlas Books, New Delhi
18. Anonymous (2004). Environmental and Pollution Loss: Atlas Books, New Delhi
19. Singh MP and Soma D (2004). Bioresources and Gene Pool Conservations. Biopublications, New Delhi

Breeding for Biotic Stress

Credits: 4+1+0
Teaching hours: 50

1. **Introduction:** Definition, importance and general classification of biotic stresses, disease triangle and tetrahedron, Koch's postulates, stages in development of disease in plants. 4

2. **Major disease and pests of economically important crops** (Etiology, Symptoms and control) 26

   a. Bacterial diseases: Red stripe of sugarcane; Blight of Rice, Soft Rot of potato

   b. Fungal diseases: Loose smut of wheat, Hill bunt and Karnal bunt of wheat; Flag smut of wheat; Yellow rust and black rust of wheat, Blast and Brown spot of paddy, Sheath blight of Rice, Red rot of sugarcane, Sheath blight of Maize, Powdery mildew of cereals Early blight and late blight of potato, White rust of crucifers,

   c. Nematodes Disease: Ear cockle of wheat; Molya disease of wheat and barley; Root knot of vegetable crops.

   d. Viral diseases: leaf curl and mosaic of tomato and chilli; yellow vein mosaic and genation leaf curl of bhindi (okra), cotton leaf curl, yellow mosaic of mungbean, bunchy top of banana, sterility mosaic of pigeon, Tungro disease of rice.

   e. Physiological disorders: Black heart of potato; tip burn of paddy; khaira disease of rice.

   f. Brief idea about the pests of rice, wheat, maize, Sorghum, pea, gram, sugarcane and cotton.

3. **Host defence response to pathogen invasions-** Biochemical and molecular mechanism**,** acquired and induced immunity, systemic acquired resistance (SAR), host-pathogen interaction, gene-for-gene hypothesis, molecular evidence for its operation and exceptions. 8

4. **Types and genetic mechanisms of resistance to biotic stresses:** horizontal and vertical resistance in crop plants, Quantitative resistance, classical and molecular breeding methods (MAS) - measuring plant resistance using plant fitness. Phenotypic screening methods for major diseases and pests, recording of observations. 8

5. **Management:** Exploitation of wild relatives as a source of resistance, Use of transgenics in management of biotic stresses. 4

Suggested Readings

1. Tarr, S.A.J. (1972). The Principles of Plant Pathology. Macmillan Press, London.
2. Agrios, G.N. (1998). Plant Pathology. Acad. Press, New York.
3. Russel GE. (1978) Plant Breeding Pest and Disease Resistance. Butterworths.
4. Campbell, R. (1989). Biological Control of Microbial Plant Pathogens. Cambridge Univ. Press.
5. Fenemore. P.G. (1984). Plant Pests and Their Control. Butterworths, London.
6. Mundkur, B.B. (1949). Fungi and Plant Diseases. Macmillan & Co, London.
7. Rangaswami, G. (2002). Diseases of Crop Plants in India. Prentice Hall of India, New Delhi.
8. Singh, R.S. (2002). Introduction to Principles of Plant Pathology. Oxford & IBH Publishing Co. New Delhi.
9. Walker, J.C. (1969). Plant Pathology. McGraw Hill Book Co., New York.
10. Roger Hull (2013) Plant virology, 5th Edition. Academic Press.

Molecular Genetics

Credits: 4+1+0
Teaching hours: 50

1. **Genetic material:** DNA and RNA as genetic material (experimental evidences; Griffith, Harshey and Chase, and TMV); structure of DNA (including Z-DNA, and Shasisekharan's RL model); supercoiling of DNA; different types of RNAs and their roles; differences between DNA and RNA. 2

2. **DNA replication (in prokaryotes and eukaryotes):** Unwinding proteins; role of RNA polymerases for synthesis of RNA primers, DNA polymerases in prokaryotic and eukaryotic DNA replication; semi- conservative, discontinuous and bi-directional replication; RNA primers; role of a number of proteins in prokaryotic and eukaryotic DNA replication; models of replication. 4

3. **Organization of genetic material:** Chromosome ultra-structure and nucleosome concept; packaging of DNA as nucleosomes in eukaryotes; techniques used for discovery of nucleosome; structure and assembly of nucleosomes, solenoid; phasing of nucleosomes; DNA content and C- value paradox, repetitive and unique sequences; overlapping, pseudo, cryptic and split genes; satellite DNA's; selfish DNA (including transposons and retroposons); Centromere and telomere. 6

4. **Genetic code (including mitochondria genetic code):** Deciphering of code *in vitro* and *in vivo* (use of mutations -base replacement, frame shift and suppressor mutations. 2

5. **Primary, secondary, tertiary and quaternary structures of proteins:** Protein folding problem and second half of the genetic code; elementary idea of prions. 4

6. **Protein synthesis apparatus:** Transfer RNA and ribosomes (including Rosen Kornberg's work); transfer RNA synthetases and second genetic code. 2

7. **Transcription of message:** Central dogma (including reverse transcription), prokaryotic RNA polymerases and eukaryotic RNA polymerases (I to V); promoters for transcription initiation (pribnow box, TATA box, CAAT box, GC box, etc.); enhancers and silencers; transcription initiation complex (including scaffold complex); different transcription factors for different RNA polymerases in eukaryotes (including mediators); DNA binding and activation domains in transcription factors; elongation of RNA transcript; termination of transcription. 8

8. **Processing of RNA transcript:** Different mechanisms of RNA splicing; spliceosomes; alternative splicing (exosomes); ribozymes; snRNAs;; RNA editing (editosomes) 4

9. **Translation of message:** Initiation in prokaryotes and eukaryotes; Kozak's hypothesis; role of initiation factors; initiation complex; elongation of polypeptide (EF – Tu, EF – Ts & EF-G; eEF1 and eEF2); termination of polypeptide. 4

10. **Maturation and modification of released polypeptide:** Transport and modification of polypeptide and signal peptidases; protein splicing of inteins; elementary idea of protein folding; protein degradation (ubiquitin and proteasome). 2
11. **Regulation of gene expression in prokaryotes:** The operon concept and its recent modifications, positive and negative controls; leader sequence and attenuation; feedback inhibition. 4

12. **Regulation of gene expression in eukaryotes:** Regulation of transcription, Britten–Davidson model, histone and non-histone proteins in regulation, signal transduction pathways, transcription factors (DNA-binding and activation domains), rearrangement of DNA; post-transcriptional regulation-alternative splicing, mRNA stability and translational control, UTRs of mRNA, miRNA, siRNA, riboswitches, antiswitches. 6

13. **Signal perception and transduction:** Cell receptors and signaling molecules e.g. ethylene signaling pathway, salicylic acid and jasmonate signaling pathway). 2

Suggested Readings

1. Albert B, Jhonson A, Lewis J, Raff M, Roberts K and Walter P (2002). Molecular Biology of the Cell, 4/e. Graland Science, New York
2. Freifelder D and Malacinski GM (1993). Essentials of Molecular Biology 2nd Ed. Johns and Bartlett Publishers, Boston
3. Gupta PK (2003). Cell and Molecular Biology, 2/e. Rastogi Publications, Meerut
4. Kahl G (2001). Dictionary of Gene Technology (2 Vols). Wiley-VCH Verlag GmBH & Co. KGaA, Weinheim
5. Lewin B (2007). Gene IX.. Oxford Univ. Press, New York.
6. Primrose SB, and Twyman RM (2006). Principles of Gene Manipulation, 7/e.. Blackwell Science
8. Rapley R and Harbon S (Eds.) (2004). Molecular Analysis and Genome Discovery. Wiley
9. Watson JD et al. (2004). Molecular Biology of Gene.
10. Wilson J and Hunt T (1994). Molecular biology of the Cell: the Problems Book. Garland Publishing Inc., New York

Computer Applications and Bioinformatics

Credits: 4+1+0
Teaching hours: 50

Part I

1. **Introduction to computers:** Types, general characteristics, input/output units, memory, internal representation of data (binary, octal and hexa-decimal system, bits and bytes). 2

2. **Brief idea of operating systems:** Disc operating systems (DOS), UNIX and its versions (Linux), WINDOWS and its upgraded versions. 4

3. **Introduction to networking:** LAN (local area network), WAN (wide area network), MAN (metropolitan area network) including www (world wide web). 2

4. **Microsoft (MS) office and its applications:** Introduction to MS Excel and its applications for statistical analyses with particular reference to agricultural data (tabular and graphical representation of data, analyses of variance, regression and correlation); introduction to MS Word and its application for document preparation; power Point and its application for preparing presentations. 6

5. **Introduction to statistical packages:** Introductory knowledge of SPSS (Statistical Package for the Social Sciences), SAS (Statistical Analysis Software) packages for statistical analysis of agricultural data, handling software for data analyses. 6

Part II

6. **An overview of bioinformatics:** Introduction, objective of bioinformatics, kind of data used in bioinformatics, multiplicity of data and redundancy, major bioinformatics databases, data integration, data analysis. 2

7. **Sequence and structure databases**: Nucleic acid data bases (EMBL, GenBank, DDBJ), protein data bases (SWISS-PROT, TrEMBL PIR-PSD, UNIProt as a single database), URLs (Uniform resource locators) of databases, SWISS-2DPAGE, KEGG, COGS, PROSITE, etc. Sequence cluster database (ProDom, Cluster, SYSTERS, ProtoMap); structure databases (CCDC, DSSP, SCOP, CATH, etc.). 4

8. **Alignment of sequences:** Introduction to sequence analysis, models for sequence analysis (local, global, end free space alignment and gap penalty), introduction to applications of dot matrices, application of FASTA and BLAST programmes (introduction, BLAST output, significance of BLAST results, recommended steps in BLAST, BLAST programmes), comparison between FASTA and BLAST programmes. 8

9. **Assembly of nucleotide sequences**. 2

10. **Agricultural biotechnology:** Introductory account of NCBI's GenBank, (dbEST, UniGene), TIGR (TIGR Gene Indices); UK CropNet, PlantGDB (TCs, TUGs,

GeneSequer); GrainGenes (Gramene, Komugi, North American Barley Genome Project, Rice Genome Research Program, US Wheat Genome project, US MAS; websites for

major centres of crop research); GMO food resources, etc.), MaizeDB; TAIR, CUGI; browsing and querying NPGS website; softwares for genome research (phred/phrap/consed; crossmatch; TIGR's suite of tools; EBI's suit of tools; Staden package). 8

11. Access to literature: Bibliographic databases; (Boolean searching, limiting searches, history functions to combine different searches); databases (PubMed/MEDLINE; ISI Citation Database, Current contents®; BIOSIS Previews; Pascal; EMBASE; The Cochrane Reviews, AGRICOLA, Agripedia etc.); PubMed and other databases; on-line access to abstracts and full text of articles; online books; free and paid access). 6

Suggested Readings

1. Gear CW (1980). Computer Organization and Programming. McGraw-Hill Inc., New York
2. Gotefried BS (1986). Theories and Problems of Programming with BASIC. Schaum's Outline Series, McGraw-Hill Book Company, Singapore
3. Lipschutz MM, Lipschutz S (1981). Theories and Problems of Data Processing. Schaum's Outline Series, McGraw-Hill Book Company, Singapore
4. Subramanian N (1986). Introduction to Computer. Fundamentals of Computer Science. Tata McGraw-Hill Publishing Company Ltd., New Delhi
5. Rajaraman V Fundamentals of Computers. Prentice-Hall of India (Pvt.) ltd., New Delhi.
6. Sansom CE, Horton RM Eds. (2004). Internet for Molecular Biology. Oxford Univ. Press
7. Grant CAR, Helmer-Citterich M Eds. (2004). The Internet for Cell and Molecular Biologists, 2/e. Horizon Bioscience
8. Mount DW (2004**).** Bioinformatics: Sequence and Genome Analysis, 2/e. Cold Spring Harbor laboratory Press, USA
9. Brown SM (2000). Bioinformatics: A Biologist's Guide to Biocomputing and the Internet. Eaton Publishing
10. Rastogi SC, Mendiratta N, Rastogi P (2003). Bioinformatics: Concepts, Skills and Applications. CBS Publishers, New Delhi
11. Baxevanis AD, Ouellette BFF Eds. (2001). Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins (2nd Edition). John Wiley & Sons
12. Sharma TR (2009). Genome Analysis and Bioinformatics: A Practical Approach. IK International, New Delhi

Pant Physiology

Credits: 4+0+0
Teaching hours: 50

1. **Cell physiology:** Cell organelles and their physiological functions, structure and physiological functions of cell wall, cell inclusions, cell membrane structure and functions. 4
2. **Water uptake and transport mechanism:** water and its role in plants, water potential of plant cells, mechanism of water uptake by roots-transport in roots, aquaporins, movement of water in plants – Mycorrhizal association on water uptake. **Physiology of water stress in plants:** Influence of water stress at cell, organ, plant and canopy levels. Indices for assessment of drought resistance. 8
3. **Mechanism of transpiration:** Stomata structure and function – mechanism of stomatal movement, anti-transpirants, transpiration mechanism in plant, factors influencing transpiration rate. 4
4. **Role of mineral nutrients in plant metabolism:** Essential elements and their resources, classification based on function of elements in plants, mechanisms of uptake and translocation of minerals in plants, physiological and metabolic functions of mineral elements, critical levels, deficiency symptoms, nutrient deficiency and toxicity, foliar nutrition. 6
5. **Mechanism of photosynthesis:** Photosynthesis and its importance in bio productivity. Photochemical process, photochemical reactions, CO_2 reduction in Calvin cycle, supplementary pathway of C fixation in C_4 and CAM plants and its significance, differences among C_3, C_4 and CAM plants, photorespiration and its relevance, translocation of photosynthates and its importance in sink growth, source-sink relationship. 8
6. **Plant respiration and lipid metabolism:** Mechanism of respiration, glycolysis, Kreb's cycle, electron transport system, growth and maintenance of respiration, cyanide resistant respiration and its significance.
   Storage, protective and structural lipids, biosynthesis of fatty acids, diacyl and triacyl glycerol, fatty acids of storage lipids. Secondary metabolites and their significance in plant defence mechanism. 8
7. **Nitrogen metabolism:** Inorganic nitrogen species (N_2, NO_3 and NH_3) and their reduction to amino acids, protein synthesis and nucleic acids, nitrogen cycle. 4
8. **Plant growth regulators:** Hormonal regulation of growth and differentiation, plant growth hormones and their physiological role, synthetic growth regulators, growth retardants, apical dominance, senescence, fruit growth, abscission. 2
9. **Some stress related enzymes in plants** 2
10. **Photo morphogenesis:** Photoreceptors, phytochrome, cryptochrome. Physiology of flowering: Photoperiodism and vernalization. 4

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Suggested Readings

(i) Salisbury FB and Ross, CW (1986) Plant Physiology, CBS Publishers & Distributors,

New Delhi.

(ii) Taize L and Zeiger E (2006) Plant Physiology. Sinauer Associates, Inc, Publishers, Sunderland, Massachusetts, USA.

(iii) Hopkins WG and Huner NPA (2004) Introduction to Plant Physiology. John Wiley & Sons.

(iv) Oxlade Edwin (2010) Plant Physiology: The Structure of Plants Explained. In-focus: Studymates.

Semester III

Breeding for Abiotic Stress and Quality

Teaching credits: 4+1+0
Teaching hours: 50

1. **Introduction:** Classification of abiotic stresses, stress inducing factors – moisture/drought stress, water logging and submergence, acidity, salinity/alkalinity/sodicity, high/low temperature, wind, etc. Stresses due to soil factors and mineral toxicity, physiological and phonological responses. Phenotypic screening techniques and data recording. 6
2. **Breeding for abiotic stress (drought, salt and temperature) tolerance:** Genetics of abiotic stress resistance, genes and genomics in breeding cultivars suitable to low water regimes and water logging & submergence, high and low freezing temperature, Utilizing MAS procedures identifying resistant types in important crops like rice, sorghum, wheat, cotton. Breeding for resistance to stress caused by toxicity, deficiency, and pollutants/contaminants in soil, water and environment. Mechanisms of stress tolerance (role of proline, glycine betaine, dehydration response elements, trehalose) screening for tolerance, sources of tolerance, breeding approaches for improved tolerance to abiotic stress including marker-assisted selection. 20
3. **Breeding for nutritional quality traits (protein, oil, vitamins and iron):** Breeding for improved protein content and quality in cereals and legumes, sources of quality traits, breeding approaches, achievements; breeding for improved oil content and quality, breeding approaches and achievements; biofortification {including Fe (rice) and Zn, vitamins (golden rice and maize); quality protein maize (QPM). 12
4. **Breeding by design:** Mapping of loci involved in all agronomically relevant traits; introgression line libraries; chromosome haplotype; breeding by design. 6
5. **Plant ideotype:** Ideotype concept, ideotypes of wheat, rice, maize, *Brassica* species, cotton, pigeon pea, mung bean and chickpea, super plant types. 6

Suggested Readings

1. Singh, B. D. (2007). Plant Breeding. Kalyani Publishers, New Delhi
2. Chahal, G. S. and Gosal, S. S. (2003). Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches. Narosa Publishing House, New Delhi
3. Simmonds, N. W. (1979). Principles of Crop Improvement. Longman, London
4. Poehlman, J. M. and Sleper, D. A. (1995). Breeding Field Crops, 4/e. Iowa State Univ. Press, Iowa
5. Gupta, P. K. (2003). Biotechnology and Genomics. Rastogi Publications, Meerut
6. Chopra, V. L. (ed.) (2000). Plant Breeding: Theory and Practice, 2/e. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi
7. Hayward, M. D. , Bosemark, N. O. and Romagosa, I. (eds.) (1993). Plant Breeding: Principles and Prospects. Chapman & Hall, London
8. Briggs FN and Knowles, PF (1967). Introduction to Plant Breeding. Reinhold Company, New York
9. Simmonds NW and Smartt J (2000). Principles of Crop Improvement, 2/e. Blackwell Science, Malden
10. Fehr, W. R. (1987). Principles of Cultivar Development. Vol. 1&2. Theory and Technique. Macmillan Pub. Co., New York
13. Schlegel, R. J. (2003) Encyclopedic Dictionary of Plant Breeding. Food Products Press
14. Peleman, J. D. and van der Voort, J. R. (2003). Breeding by design. Trends in Plant Sci 8: 330-334
15. Nguyen, H. T. and Blum, A. (2004). Physiology and Biotechnology Integration for Plant Breeding. Marcel Dekker
17. Carena, M. J. (ed) (2009). Handbook of Plant Breeding: Cereals. Springer, USA

Population and Biometrical Genetics

Credits: 4+1+0
Teaching hours: 50

1. **Genes in populations: estimation of gene frequencies:** Hardy -Weinberg law. 2

2. **Forces changing gene frequencies**: Migration, mutation, selection; random drift and inbreeding, equilibrium in small populations; population differentiation and pooling of sub-populations (Wahlund effect), F-statistics (F_{ST}, F_{IS} and F_{IT}). 6

3. **Inbreeding:** Coefficient of inbreeding; pedigreed populations (relation of F with heterozygosity); irregular system of mating. 6

4. **Correlation studies**: Genotypic and phenotypic correlations and path coefficient analysis in relation to crop improvement. 6

5. **Heritability and selection response**: Methods of estimation and their application in plant breeding; co-heritability. 4

6. **Simultaneous selection models**: Discriminant function; classical, restricted and general selection indices. 4

7. **Combining ability and gene effects**: General and specific combining abilities; additive dominance and epistatic gene effects; line × tester analysis ; diallel analysis (Hayman and Griffing's approaches): generation-means analysis, scaling tests (six , five and three parameters models); North Carolina Designs, triple test cross. 10

8. **Genotype-environment interaction and stability analysis**: Varietal evaluation in multi-location / multi-year trials; estimation of g × e and stability parameters following the models of Finlay and Wilkinson, Eberhart and Russell, Perkins and Jinks, Freeman and Perkins; AMMI model. 10

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9. **Use of molecular tools in population genetics:** Neutral theory of evolution, brief idea of coalescent theory of evolution; population structure and genetic diversity analysis; directional and balancing selection. 2

Suggested Readings

1. Falconer, D. S. (1960). Introduction to Quantitative Genetics. Ronald Press, New York.
2. Frey, K. J. (Ed.) (1966). Plant Breeding. The Iowa State University Press, Ames.
3. Jinks, J. L. and Mather, K. (1971). Biometrical Genetics, Chapman and Hall, London.
4. Jinks, J. L. and Mather, K. (1978). Introduction to Biometrical Genetics. Chapman and Hall, London.
5. Jain, J. P. (1982). Statistical Techniques in Quantitative Genetics. Tata McGraw-Hill Publishing Co. Ltd., New Delhi.
6. Kempton, R. A. and Fox, P. N. (1997). Statistical Methods for Plant Variety Evaluation. Chapman and Hall

7. Lynch, M. and Walsh, B. (1998). Genetics and Analysis of Quantitative traits. Sinauer Associates
8. Singh, R. K. (1977). Biometrical Methods in Quantitative Genetics Analysis. Kalyani Publishers, Ludhiana.
9. Strickberger, M. W. (1988). Genetics, 3/e. Macmillan Publishing Co., Inc., New York.
10. Verma, M. M. and Gill, K. S. (1975). Genotype–Environment Interaction–Its Measurement and Significance in Plant Breeding. PAU, Ludhiana.

Heterosis and Its Exploitation

Credits: 4+1+0
Teaching hours: 50

1. **Definition and historical aspects of heterosis:** Definition, pre-Mendelian and post-Mendelian aspects of heterosis 2

2. **Genetic and molecular bases of heterosis:** Dominance and over-dominance theories, inbreeding and heterosis; possible role of epistasis in heterosis; estimation of genetic diversity and the expression of heterosis; physiological, biochemical, cytoplasmic, organellar and molecular basis for expression of heterosis; single gene/mutant heterosis. 8

3. **Exploitation of heterosis:**
   (a) Extent of heterosis and its exploitation. 2
   (b**)** Male sterility and self incompatibility for hybrid seed production: development and use of cytoplasmic, genetic, cytoplasmic genetic male sterility system, environmental sensitive genetic male sterility (EGMS) and chemical hybridizing agents (CHAs), self-incompatibility for hybrid seed production. 4
   (c) Pistillate plants and hybrid seed production 2
   (d) Development of inbred lines and hybrid cultivars: Development and evaluation of inbreds and heterotic grouping in maize, genetic improvement of inbred lines, double cross, double top cross and single cross hybrids 4
   (e) Apomixis and fixation of heterosis 2
   (f) Tertiary trisomic and hybrid seed production. 2

4. **Current status of exploitation of heterosis in important crops:** Rice, wheat, maize, sorghum, pearlmillet, sunflower, cotton, vegetables, ornamental plants, pigeonpea, rapeseed mustard. 12

5. **Heterosis in population development:** Development and exploitation of F_2 hybrids, synthetics and composites (e.g cotton) 2

6. **Biotechnological applications in heterosis breeding:** (a) *Barnase* and *barstar* genes in hybrid seed production; (b) marker-assisted heterosis breeding in maize, pearl millet and rice; (c) possible use of molecular markers in selection of diverse parents for hybrid breeding. 4

7. **Hybrid seed production and role of the hybrids in enhancing crop productivity in India** 2

Suggested Readings

1. Singh, B. D. (2003). Plant Breeding. Kalyani Publishers, New Delhi
2. Chahal, G. S. and Gosal, S. S. (2003). Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches. Narosa Publishing House, New Delhi
3. Poehlman, J. M. and Sleper, D. A. (1995) Breeding Field Crops, 4th. edition. Iowa State Univ. Press, Ames, Iowa

5. Gupta, P. K. (2003). Biotechnology and Genomics. Rastogi Publications, Meerut.
6. Chopra, V. L. (ed.) (2000). Plant Breeding: Theory and Practice, 2/e. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi
7. Smith, R. H. (1992). Plant Tissue Culture Academic Press Inc., San Diego
8. Simmonds, N.W. and Smart, J. (2000). Principles of Crop Improvement. 2nd Edition. Blackwell Science, Malden, MA
9. Fehr, W. R. (1987) Principles of Cultivar Development. Vol. 1. Theory and Technique. Macmillan Pub. Co., New York
10. Fehr, W. R. (1987). Principles of Cultivar Development. Vol. 2. Crop Species. Macmillan Pub. Co., New York
11. Fehr, W. R. and Hadley, H. H. (1980) Hybridization of Crop Plants. American Society of Agronomy, Madison, WI
12. Banga, S. S. and Labana, K. S. (1983). Production of F_1 hybrids using ethrel induced male sterility in Indian mustard. J. Agric. Sci. Camb. 101:453-455
13. Kalloo, G. (1995). Heterosis breeding in vegetable crops: present status and future prospects. In: Hybrid Research and Development (Rai M and Mauria S, eds.). Indian Society of Seed Technology, New Delhi, pp 165-174.
14. Paroda, R. S. (1995). Hybrid technology for improving productivity of cereals in Asia: Issues and strategies. In: Hybrid Research and Development (Rai M and Mauria S, eds.). Indian Society of Seed Technology, New Delhi, pp 7-18.
15 Rai, M. and Mauria, S. (eds.) (1995). Hybrid Research and Development. Indian Society of Seed Technology, New Delhi.
16. Rai, B. (1979). Heterosis Breeding. Agro Biological Pub., Delhi.
17. Mukherjee, B .K. Heterosis Phenomenon.
18. Coor and Pandey, S. (eds.) (1999). Genetics and Exploitation of Heterosis.

Plant Biotechnology

Credits: 4+1+0
Teaching hours: 50

1. **Crop biotechnology and its scope:** An introduction 2

2. **Plant organ, tissue and cell culture**: Totipotency; micro-propagation and its uses; somaclonal variation and its use in crop improvement; embryo culture; anther culture; somatic embryo; artificial seeds; techniques of protoplast culture, regeneration and somatic cell hybridization, achievements and limitations, utility in improvement of crop plants; application in production of secondary metabolites and transformations. 6

3. **Elementary idea of theory and application of molecular techniques:** Centrifugation; spectrophotometry, MALDI-TOF; autoradiography, electrophoresis including pulse field and other tracer techniques; micro arrays; biosensors for agriculture. 4

4. **Post-transcriptional gene silencing (PTGS):** VIGS and RNAi and their use in functional genomics and crop improvement. 2

5. **Biofertilisers and bioinsecticides**: A brief idea of commonly used biofertilizers and Biopesticides 4

6. **Restriction enzymes:** Type I, II, and III enzymes; frequent and rare cutters; isoschizomers. 2

7. **Vectors and gene cloning:** Plasmid, phage, cosmid, phagemid vectors, BAC, PAC and YAC vectors; expression vectors; binary and shuttle vectors. 4

8. **Libraries and molecular probes:** Construction and screening of genomic and cDNA libraries; BAC libraries and assembly of BACs into contigs, molecular probes and their preparation, labeling and applications; chromosome walking and chromosome jumping. 4

9. **Polymerase chain reaction (PCR):** Basic PCR, designing of primers (including available softwares), different schemes of PCR (including RT-PCR); application of PCR; electronic-PCR
(e-PCR) 4

10. **Methods of gene transfer in plants:** *Agrobacterium* mediated gene transfer (dicots and monocots), directDNA delivery methods (microinjection, particle gun method electroporation); gene targeting (including zinc finger nucleases). 4

11. **Transgenic plants in dicots and monocots:** Utility of transgenics in basic studies and in crop improvement (resistance for biotic and abiotic stresses; barnase and barstar for hybrid seed production); molecular farming for production of foreign proteins and edible vaccines; biosaftey issues including risks associated with transgenic crops; biosafety regulations (role of IBC, RCGM and GEAC or NBRA). 6

12. **A brief idea of DNA-based molecular markers:** Restriction Fragment Length Polymorphism (RFLP); Randomly Amplified polymorphic DNA (RAPD); Simple Sequence Repeats (SSRs); Sequence Tagged Sites (STSs); Amplified Fragment Length Polymorphism (AFLP) and its variations (such as SAMPL, etc.); Single Nucleotide Polymorphisms (SNP), DArT markers, etc. 4

13. **A brief idea of application of molecular markers:** Construction of molecular maps (using F_2, DH, RILs); gene tagging using bulked segregant analysis (BSA) and near isogenic lines (NILs); QTL analysis; map-based cloning of genes; elementary idea of marker-assisted selection (MAS) in plant breeding. 4

Suggested Readings

1. Ammirato, P. V., Evans, P. V., Evans, D. A., Sharp, W. R. and Yamada, Y. (Eds.) (1984). Handbook of Plant Cell Culture. Vols. 1, 2 & 3. MacMillan Publishing Co, New York.
2. Dodds, J. H. and Roberts, L. W. (1985). Experiments in Plant Tissue Culture. Cambridge University Press, Cambridge.
4. Mantell, S. H. and Smith, H. (Eds.) (1983). Plant Biotechnology. Cambridge University Press, Cambridge.
5. Swaminathan, M. S. (1991). Biotechnology in Agriculture – A dialogue. MacMillan India, New Delhi.
6. Kung, S. and Arntzen, C. J. (Eds.). (1989). Plant Biotechnology. Butterworth, Boston.
8. Grierson D (Ed.). (1991). Plant Genetic Engineering: Plant Biotechnology Series, Volume I. Blockie, Glasgow, London.
9. Charles, S. G. and Robert, T. F. (1992). Transgenic Crops. Sci. Am. June 1992, pp. 62 – 69.
10. Bengochea, T. and Dodds, J. H. (1986). Plant Protoplasts: A Biotechnological Tool for Plant Improvement. Chapman & Hall, New York.
11. Joshi, P. (2002). Genetic Engineering and Its Applications. Agrobios (India), Jodhpur
12. Trivedi, P. C. (2000). Plant Biotechnology: Recent Advances. Panima Publishing Corporation, New Delhi
13. Chawla, H. S. (2000). Introduction to Plant Biotechnology. Oxford & IBH Publishing CO. Ltd., New Delhi
14. Lorz, H. and Wenzel, G. (2004). Biotechnology in Agriculture and Forestry. Springer-Verlag
15. Henry, R. J. (2001). Plant Genotyping: The DNA Fingerprinting of Plants. CABI Publishing, Oxon, UK
16. Singh, B. D. (1998). Biotechnology. Kalyani Publishers, Ludhiana
17. Miesfeld, R. L. (1999). Applied Molecular Genetics. John Wiley & Sons
18. Primrose, S. B., Twyman, R. M. and Old, R. W. (2001). Principles of Gene Manipulation, 6/e. Blackwell Science
19. Kahl, G. (2001). Dictionary of Gene Technology (2 Vols). Wiley-VCH Verlag GmBH & Co. KGaA, Weinheim
20. Rapley, R. and Harbon, S. (Eds.) (2004). Molecular Analysis and Genome Discovery. Wiley VCH.

Global Food and Nutritional Security

Credits: 4+0+0
Teaching hours: 50

1. **Introduction**: Major sources of human foods in India and other countries and their relative contribution to food basket; food production and productivity; food production during 20th and 21st century; food security (supply and demand) in: (i) Asia, (ii) Africa, (iii) Other countries; yield potential and yield gaps. 6
2. **Sustainable intensification of food production system:** Major crops (wheat, rice, maize, mustard, chickpea, pigeonpea, groundnut) for food security and their contribution to world food requirement; Crop Varieties and Cropping Systems. 8
3. **Reducing risks to food production and distribution system :** Factors affecting food and nutritional security; brief idea about (i) human health including diseases; (ii) climate change and green house effect/global warming; (iii) socio-economic factors; (iv) yield losses due to biotic and abiotic stresses; (v) Food losses during storage; (vi) Agriculture food distribution system. 14
4. **Food Policy and Food Security**: **Efforts/suggestions for possible future solutions**: Definitions and meaning; concept of zero hunger by 2030, brief idea about world food crisis, role of UNO, FAO, NARS, National food security bill and act 2013. 8
5. **Nutritional security and measures for achieving nutritional security:** Current nutritional status in India and other major countries. Causes of malnutrition; Role HarvestPlus; Fortified foods; Hidden hunger and Biofortification of food crops to reduce malnutrition; nutrients use efficiency in food crops; Nutritional self reliance; Emergency nutrition (Ensuring good nutrition in emergency aid). 10
6. **National and Global policies for nutritional security:** Assessing, analyzing and monitoring nutrition situations; World declaration and plan of action for nutrition; The National Nutrition Monitoring Bureau (NNMB). 4

Suggested Readings

1. Egli DB (2008). Comparison of corn and soybean yields in the United States: Historical trends and future prospects. Agronomy Journal 100(3):S79–S88.
2. FAO (Food and Agriculture Organization of the United Nations) The State of Food Insecurity in the World. Rome: Author; 2008.
3. Claudia Trentmann C. (2015) Sustainable Food and Nutrition Security. Eds: Behrens-Shah P. Deutsche Welthungerhilfe e.V. Friedrich-Ebert-Strabe, Bonn, Germany
4. Improving Diets and Nutrition: Food-based Approaches. Eds: Thompson B and Amoroso L. (2014) The Food and Agriculture Organization of the United Nations and CABI, USA
5. Von Braun, J. (2013) Food and Nutrition Security – the concept and its realization. Bread and Brain – Education and Poverty Workshop of Pontifical Academies of Sciences and Social Sciences
6. Horton, R., Lo, S. (2013) Nutrition: a quintessential sustainable development goal. In: The Lancet, Volume 382, Issue 9890, p. 371 – 372
7. Taylor, A., Dangour, A. D., Reddy, K. S. (2013) Only collective action will end undernutrition. In: The Lancet, Volume 382, Issue 9891, p. 490 - 491

Semester IV

Advanced Genetics

Credits: 4+1+0
Teaching hours: 50

1. **Genetics and biochemistry of cell cycle (role of reversible phosphorylation):** Genetic vs. biochemical approaches; mitotic cell division in yeast; variation in mitotic cell cycle; central cell cycle control system; cell cycle check points cyclin dependent kinases (Cdks) and cyclins; meiotic cell division; dynamics of chromosome movements during cell division; role of degradation of proteins (proteolysis) in cell cycle. 6

2. **Mechanism of gene mutation:** Target theory, peroxide formation, UV and thymine dimers, incorporation of base analogues and chemical alteration in nucleic acids; radiation damage and repair of DNA (photo–repair, excision repair; recombination repair, adaptive response); site specific mutagenesis; insertion mutagenesis, TILLING. 8

3. **Molecular mechanism of homologous recombination:** Crossing over, gene conversion (chiasma type or precocity, Billing's theory, hybrid DNA models of Whitehouse and Holliday); recombinases, and resolvases in prokaryotes and eukaryotes. 4

4. **Molecular mechanism of site specific recombination:** Invertases/resolvase system; integrase system; integrons and mobile gene cassettes. 2

5. **Organellar genetics:** DNA in mitochondria and chloroplasts; molecular mechanism of division of mitochondria and chloroplast; techniques to locate genes on organellar DNA; petite character in yeast; male sterility; resistance to antibiotics in *Clamydomonas;* circular genetic maps of chloroplasts and mitochondria. 6

6. **Gene mapping in bacteria, viruses, algae and fungi (including parasexual cycles):** Methods of transfer of genetic material in bacteria (transformation, conjugation and transduction); linkage maps in bacteria; replication and recombination in viruses; tetrad analysis, mitotic recombination and chromosome mapping and gene conversion in fungi and algae; somatic crossing over in *Drosophila*, mitotic recombination and parasexual cycle in *Aspergillus.* 10

7. **Plasmids, transposons and retroelements:** Plasmids, IS sequences or IS elements, transposons and controlling elements, retroelements, mechanism of transposition; uses of transposons. 4

8. **Molecular mechanism of antibody diversity:** Structure of Ig molecules; DNA rearrangement and class switching in antibody production. 2

9. **Developmental genetics:** Genetics of development (homeotic genes in initiation, development and for gene transfer with examples of embryo development in Drosophila and for flower development in *Arabidopsis*-ABCDE model). 4

10. **Epigenetics and epigenomics:** DNA methylation and histone modification; histone code. 4

Suggested Readings

1. Auerbach, C. (1976). Mutation Research: Problems, Results, and Perspectives. Chapman and Hall. London.
2. Bacq, Z.M. and Alexander, P. (1966). Fundamentals of Radiobiology. Pergamon Press.
3. Beale, G. and Knowles, J. (1978). Extranuclear genetics. Edward Arnold, London.
4. Fincham, J.R.S. (1983). Genetics. John Wright and Sons Ltd. Bristol.
5. Freese, E. (1963). Molecular mechanism of mutation. Molecular Genetics Part I. (Ed. J.H. Taylor). Acad. Press.
6. Gaul, H. (1964). Mutations in Plant Breeding. Radiation Botany 4: 155 – 232.
7. Howard – Flanders, P. (1981). Inducible repair of DNA. Sci. Am. 245 (5): 56.
8. Strickberger, M. W. (1988). Genetics 3/e Macmillan Publishing Co. Inc., New York.
9. Griffith et al. (2004). An Introduction to Genetic Analysis 8th Ed. W.H. Freeman & Co., New York.
10. Gupta, P. K. (2004). Cell and Molecular Biology. Rastogi Publications, Meerut
11. Gupta, P. K. (2003). Genetics 3rd Ed. Rastogi Publications, Meerut
12. Snustad, D. P., Simmons, N. J., and Jenkins, J. B. (2003). Principles of Genetics. John Wiley and Sons, New York
13. Hartwell, L. H. et al. (2000). Genetics: From Genes to Genomes. McGraw Hill, New Delhi
14. Pierce, B. (2005). Genetics: A conceptual Approach 2nd Ed. WH Freeman & Co
15. Knowles. Solving Problems in Genetics.
16. Hartl, D. L. and Jones, E. W. (1997). Genetics: Principles and Analysis. Jones & Bartlett Publisher Inc.
17. Primrose, S. B., Twyman, R. M. and Old, R. W. (2001). Principles of Gene Manipulation, 6/e. Blackwell Science
18. Kahl, G. (2001). Dictionary of Gene Technology (2 Vols). Wiley-VCH Verlag GmBH & Co. KGaA, Weinheim
19. Rapley, R. (Ed.) and Harbon S (2004). Molecular Analysis and Genome Discovery. Wiley

Molecular Basis of Quantitative Inheritance

Credits: 4+1+0
Teaching hours: 50

1. **Introduction to genetics of quantitative traits (including quantitative trait loci; QTL).** 2

2. **Requisites for QTL mapping:** Mapping populations {F_2, backcross (BC), doubled haploid (DH) and recombinant inbred line (RIL) populations}, molecular linkage maps, data for QTL mapping (marker data and phenotype data). 4

3. **Statistics for QTL mapping:** Likelihood function, maximum likelihood estimates, likelihood ratio tests; the LOD score approach; expectation maximization (EM) algorithm (compare with least square method); use of EM in developing software for QTL interval mapping. 4

4. **QTL mapping:** Quantitative genetic models (single QTL model, multiple locus model), mixture model. 2

5. **Single marker analysis:** Study of joint segregation of QTL and marker genotypes through Bulked Segregation Analysis (BSA), single marker QTL analysis (SMA) using linear regression and t-test, analysis of variance. 4

6. **Interval mapping:** Maximum likelihood and regression approaches and their comparison for QTL analysis, expectation maximization algorithm, joint segregation of QTL and marker genotypes, simple interval mapping (SIM) and composite interval mapping (CIM), multiple trait mapping (multiple trait simple interval mapping and multiple trait composite interval mapping), advantages of CIM over SMA and SIM. 6

7. **Epistatic QTLs and QTL × environment interaction:** Epistatic QTL with and without main effects, QTL × environment interaction. 4

8. **Genetical Genomics and e-QTLs:** Expression profile and its genetic control. 2
9. **Bayesian approach for QTL mapping:** Introduction, Bayes' theorm, simple and conditional probabilities, advantages of Bayesian analysis. 4
10. **High resolution mapping and cloning of QTL:** Population size, molecular markers (markers from targeted region, mapped markers from orthologous regions), strategies for high resolution mapping using BSA and near isogenic lines (NILs); examples of QTL cloning. 6
11. **Linkage disequilibrium (LD):** Introduction, measures of LD, factors affecting LD, LD and association mapping in plants. 4
12. **Molecular marker-assisted breeding:** Validation of markers linked with QTL, molecular marker assisted selection (MAS) and its applications {(limited gene transfer through backcross method (foreground and background selection), gene pyramiding, etc.)}, gene transfer through advanced backcross QTL (AB-QTL) analysis. 6

13. Computer tools: Softwares for linkage analysis and map construction, softwares for QTL mapping. 2

Suggested Readings:

1. Liu, B. H. (1998). Statistical Genomics: Linkage, Mapping, and QTL Analysis. CRC Press, Boca Raton, New York, USA
2. Phillips, R. L. and Vasil, I. K. (eds.) (1994). DNA Based Markers in Plants. Kluwer Academic Publishers, Dordrecht
3. Chahal, G. S. and Gosal, S. S. (2003). Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches. Narosa Publishing House, New Delhi
4. Gupta, P. K. and Varshney, R. K. (eds.) (2004) Cereal Genomics. Kluwer Academic Publishers, Dordrecht
5. Paterson, A. H. (ed.) (1998) Molecular Dissection of Complex Traits. CRC Press, Boca Raton, New York, USA
6. Lee, P. (2004). Bayesian Statistics: An Introduction, 3/e. Hodder & Stoughton Publishers, Oxon, UK
7. Shoemaker, J. S., Painter, I. S., Weir, B. S. (1999). Bayesian statistics in genetics: A guide for the uninitiated. Trends Genet 15:354-358
8. Flint-Garcia, S. A., Thornsberry J. M. and Buckler, E. S. (2003) Structure of linkage disequilibrium in plants. Ann Rev Plant Biol 54:357-374
9. Rafalski, A. and Morgante, M. (2004). Corn and humans: recombination and linkage disequilibrium in two genomes of similar size. Trends Genet 20: 103-111

Principles and Practices of Seed Production

Credits: 4+1+0
Teaching hours: 50

1. **General aspects of seeds production technology**: History and role of seed industry (relative role of public and private sector undertakings); floral biology in relation to seed structure and development; importance of quality seed; categories of seeds (nucleus, breeder, foundation and certified); causes for the deterioration of seed quality. 6

2. **Seed production methods**: Seed production methods for self-pollinated, cross-pollinated and vegetatively propagated crops; male sterility and its use in hybrid seed production; isolation and agronomic requirements for seed production (already taught in course 12) and the techniques involved. 4

3. **Seed production of GM crops**: Isolation distances; refugia; regulatory measures. 2

4. **Seed certification and field inspection**: Purpose and necessity of seed certification; seed act 1996; seed bill 2004; field inspection and procedures; seed certification terms; rouging; field standards; national seed policy; seed legislation; seeds act and rules. 6

5. **Production of high quality seed**: Maize, bajra, sorghum, paddy, wheat and barley, pea, pigeonpea, chickpea, urdbean/ mungbean, mustard, groundnut, cotton, potato, bhindi, brinjal, tomato, cauliflower, radish and carrot; fruit species such as banana, mango, etc. 12

6. **Seed testing**: Importance, history and development; seed testing laboratory; sampling and its methods; purity analysis, germination tests and seedling evaluation; moisture test; seed dormancy; viability tests; reporting of results; seed priming; synthetic seeds; taped seeds. 10

7. **Seed processing and packaging:** Principles and practices; seed drying and conditioning; seed cleaning and grading; methods of seed packing and storage; factors affecting seed storage; problems of stored grain pests and methods to overcome them. 10

Suggested Readings

1. Anonymous (2004). International rules for seed testing. ISTA, Switzerland.
2. Douglas, J.E. (1967). Seed certification manual. NSC and Rockefeller Foundation, New Delhi.
3. Agarwal, R.L. (2003). Seed Technology. Oxford & I.B.H. Delhi.
4. Feistritzer,W.P (1975). Cereal Seed Technology, F.A.O. Agricultural Development Paper No. 98.

5. Indian Minimum Seed Certification Standards. The Central Seed Certification Board, New Delhi, 1988.
6. Chalam, G.V., Singh, A. and Douglas, J. E. (1967). Seed Testing Manual. ICAR & USDA Publication, New Delhi.
7. Nema, N. P. (1987). Principles of Seed certification and Testing.
8. McDonald, M.B. and Copeland, L. O. (1995). Principles and practices of seed Production. Chapman & Hall, London.
9. Kelly, A.F. and George, R.A.T.(eds,). (1998). Encyclopedia of Seed production of world crops. John Wiley & Sons, England.
10. Desai, B.B., Kotecha, P.M. and Salunkhe, D.K. (1995). Principles and practices of seed production. Chapman & Hall, New York.
11. Agrawal, P.K. (2002). Principles of Seed Technology. ICAR, New Delhi.
12. ISTA Handbook on Seedling Evaluation, 3/e. ISTA, Basserdorf, CH- Switzerland
13. Singh, NP, Bhardwaj, AK, Kumar, banish and Singh KM ((2004). Modern Technology on Vegetable Production. International Book Co., Lucknow
14. Singh, S. P. (2001). Seed Production of Commercial Vegetables. Agrotech Publishing Academy, Udaipur
15. Singhal, N. C. (2003). Hybrid Seed Production in Field Crops. Kalyani Publishers, New Delhi
14. Khare, D. and Bhale, M. S. (2000). Seed Technology. Scientific Publishers (India), Jodhpur

Genomics, Transcriptomics and Proteomics

Credits: 4+1+0
Teaching hours: 50

Part I. Genomics

1. **Molecular maps of genomes and comparative genomics:** Genetic maps, physical maps, EST and transcript maps, functional maps; comparative mapping, genomics and collinearity/synteny in maps. 4

2. **Isolation, sequencing and synthesis of genes and genomes:** Methods of gene isolation (use of antibody; transposon tagging; etc); chemical (Maxam and Gilbert's degradation method) and enzymatic (Sanger's dideoxy synthetic method) methods of DNA sequencing; organochemical gene synthesis, gene synthesis machines, PCR methods of gene synthesis, cDNA using reverse transcriptases; synthesis of genomes. 6

3. **Whole genome sequencing:** Whole genome shotgun sequencing; clone-by-clone or 'hierarchical shotgun' sequencing; new generation sequencing technologies (454, Illumina, ABI SOliD, single molecule and nanopore sequencing); microbial genomes (including yeast); plant genomes (*Arabidopsis* and rice); pan genomes and metagenome. 4

4. **Annotation of whole genome sequence and functional genomics:** *In silico* methods, insertion mutagenesis (T-DNA and transport insertion), VIGs, RNAi, TILLING, Eco-TILLING, management of data, gene expression and transcript profiling, EST contigs and unigene sets, use of DNA chips and microarrays. 6

5. **Comparative genomics:** Collinearity and synteny; micro-collinearity and lack of it; DNA based phylogenetic trees. 2

6. **Chemical genetics and chemogenomics**: An elementary idea. 2

Part II. Transcriptomics

7. **Significance of transcriptomics:** Differential expression of genes in different tissues/ organs and in response to biotic and abiotic stresses. 2

8. **Methods of transcriptome analysis:** (a) Sequence-based technologies (ESTs, SAGE, MPSS), (b) array-based technologies, (c) computational-based technologies. 4

9. **Transcriptome of some model plant species**: *Arabidopsis* and rice; systems biology. 2

Part III. Proteomics

10. **Significance of proteomics**: Proteomes in different tissues/organs and in response to biotic and abiotic stresses; nuclear and organellar proteomics. 2

11. **Post-translational modification of proteins**: Phosphorylation, glycosylation and sulphation, etc. 2

12. **Protein interactions and protein complexes**: Protein interactions; DNA - protein interactions, yeast two-hybrid systems; multiprotein complexes and their analysis, affinity tagging, pathway building. 4

13. **Analysis of nucleic acid / protein sequence and structure data:** Genome and proteome data using web-based tools; integration of different datasets. 2

14. **Proteome of model plant species**: *Arabidopsis* and rice. 2

15. **Methods for proteomics analysis**: SDS- PAGE, 2D-PAGE, X- ray crystallography NMR spectroscopy, isoelectric focusing (IEF), mass spectroscopy (MS), MALDI-TOF, differential display (DD), protein chips and antibody microarrays, functional protein microarrays; resolution and identification of proteins, analysis of post-translational modifications of proteins. 4

16. **Ionomics**: An elementary idea 2

Suggested Readings

1. Gupta, P. K. (2004). Biotechnology and Genomics. Rastogi Publication, Meerut.
2. Cullis, C. A. (2004). Plant Genomics and Proteomics. Agrosciences, New Delhi.
3. Reece, R. J. (2004). Analysis of Genes and Genomes. Agrosciences, New Delhi.
4. Brown, T. A. (2007). Genomes, 3/e. Garland Science, New York..
5. Stein (2003). Fundamentals of Protein Biotechnology. Atlas Books, New Delhi.

M. Sc. (Ag.) Thesis

Component-I (C_1): Periodic progress and progress reports (15%)	8
Component-II (C_2): Results of work and draft report (15%)	12
Component-III (C_3): Final viva-voce and evaluation (70%) (a) The report evaluation (40%) (b) Viva-voce examination (30%)	20
Total credits in M.Sc. (Ag.) Thesis	**40**