DEPARTMENT OF PLANT SCIENCE
Central University of Kerala, Kasaragod

M.Sc.Botany Programme

Introduction:
The course curricula in this programme is designed taking into consideration that students from various universities with different training at the UG level may join and therefore the basics and advanced topics in botany are comprehensively framed. Also the recent developments in the field of botany are integrated in each core course and also as electives. All major disciplines in the field of botany like systematics, diversity studies, plant biotechnology and genetic engineering, ecology, developmental biology, physiology and biochemistry, economic botany, plant response to pathogens and methods in plant biology are offered as core course along with basic courses like cell and molecular biology and genetics. In the past 30 years remarkable progress has taken place in understanding plant biology at the molecular level and therefore it is imperative that students are exposed to the tools of modern biology to address specific questions in botany. Keeping this in mind, there is greater emphasis in the syllabus to impart latest knowledge through courses like Omics in Plant Science and Plant Biotechnology and Genetic engineering. In addition, skill based courses like hands on experience in Organic farming and hands on experience in micropropagation and phytochemistry will give opportunities for the students to take up entrepreneurship in specific areas.

Programme outcome:
MSc botany program is designed to,

PO1: Generate postgraduates with sound theoretical knowledge and practical skills in basic and applied botany
PO2: Provide post graduates with necessary scientific skills and problem solving capability that enable them to take up innovative research in the field of botany.
PO3: Generate post graduates with the ability to synthesize scientifically based opinion in the field of botany and communicate the same to the general public.

Specific outcome:

Post graduates with adequate skills to contribute towards the conservation of the local flora and traditional plant based knowledge and education and research in plant molecular biology and plant biotechnology research.

DEPARTMENT OF PLANT SCIENCE
Central University of Kerala, Kasaragod
Syllabus of M.Sc. Botany Programme under CBCS regulation
2019-20 Academic onwards

Semester		Course code	Course Title	Hours/week		Credit
				Lecture	Practical	
Core Courses	I	BTY 5101	Plant Diversity I (Algae, Fungi, Lichens and Bryophytes)	3	3	4
		BTY 5102	Plant Diversity II (Pteridophytes, Gymnosperms and Paleobotany)	3	3	4
		BTY 5103	Ecology of Plants	3	3	4
		BTY 5104	Genetics	4	3	4
		BTY 5105	Cell and Molecular Biology	4	3	4
	II	BTY 5206	Plant Biochemistry and Plant Physiology	4	3	4
		BTY 5207	Developmental Biology of the Plants	3	3	4
		BTY 5208	Plant biotechnology and Plant genetic Engineering	4	3	4
		BTY 5209	Omics in Plant Science	4	3	4
	III	BTY 5310	Plant Systematics	4	3	4
		BTY 5311	Economic Botany	3	3	4
		BTY 5312	Plant-Pathogen Interactions	3	3	4
		BTY 5313	Methods in Plant Biology	4	3	4
	IV	BTY 5490	Dissertation*			8
Elective Courses		BTY 5001	Plant Tissue culture techniques	3	3	4
		BTY 5002	Algal bioprospecting	2	3	3
		BTY 5003	Genome stability and DNA repair	2	0	2
		BTY 5004	Recent advances in plant biology	3	0	3
		BTY 5005	Ethnobotany: Plants, People and Culture	2	0	2
		BTY 5006	Biomass and Bioenergy	3	0	3
		BTY 5007	Hands on training on Plant metabolites and Drug discovery	3	3	3
		BTY 5008	Organic Farming	1	4	3

*Students are required to start their dissertation work at the beginning of the IIIrd Semester and they have to submit the dissertation at the end of IVth semester in the prescribed format for evaluation.

Lecture credits cover tutorial and No separate credit assigned to tutorials. Practical credits cover field work and No separate credit assigned to field work.

List of Courses in Semester I

Semester	Course code	Course Title	Hours/week		Credit
			Lecture	Practical	
I	BTY 5101	Plant Diversity I (Algae, Fungi, Lichens and Bryophytes)	3	3	4
	BTY 5102	Plant Diversity II (Pteridophytes, Gymnosperms and Paleobotany)	3	3	4
	BTY 5103	Ecology of Plants	3	3	4
	BTY 5104	Genetics	4	3	4
	BTY 5105	Cell and Molecular Biology	4	3	4

BTY 5101	**PLANT DIVERSITY I (Algae, fungi, lichens and bryophytes)** (Credits 4; Theory 3hrs; Practical 3 hrs)
AIM	To study the diversity of algae, fungi, lichens and bryophytes.
Objectives	• Understanding on the classification, occurrence and habit of algae, fungi, lichens and bryophytes • Understanding the potential of this groups of plants for economical utility. • Phylogenetic relationship of this groups
Learning outcome	The learners on the completion of this course ➢ Have a deep understanding of the origin, evolution and diversity of lower plants (algae, fungi, lichens and bryophytes). ➢ Have clear idea on the nature of reproduction in lower plants ➢ Would be able to identify the various species of these groups for conservation and utilization.
Sl. No.	**Theory**
1.	**Algae:** Basic characteristics of the algae; Habitat and range of thallus structure in algae; Classificationof Algae by chloroplast evolution; Life cycle pattern; Pigmentation; Endosymbiosis and evolution of chloroplast in algae; Origin and evolution of sex in algae; Fossil algae. Algal bloom, Red tide and Algal toxins. Algae as an indicator of water pollution. Commercial application of marine algae polysaccharides. Algae for biofuel, agriculture, nutraceautical, pharmaceuticals and biomedical applications.
2.	**Salient features of major groups of algae:** A general account with emphasis on cell structure and reproduction of Prokaryotic algae (cyanobacteria) and Eukaryotic algae (*Rhodophyta, Chlorophyta, Euglenophyta, Dinophyta, Apicomplexa, Cryptophyta, Heterokontophyta (Chrysophyceae, Eustigmatophyceae, Bacillariophyceae, Xanthophyceae, Phaeophyceae, Prymnesiophyta*).
3.	**Fungi:** General characters and life history of *Myxomycota, Mastigiomycotina, Zygomycotina, Ascomycotina, Basidiomycotina and Deuteromycotina.* Classification of fungi(Aisworth,1971).Mycelial structure; Fungal tissues, hyphal growth, fungal wall and septa; and reproduction of fungi, Types of fruiting bodies in fungi, Spores and spore dispersal in fungi, Spore germination, Fungal growth and evolution. Fungal associations and their significance, (a) Symbionts - Lichens, Mycorrhiza, Fungus-insect mutualism. (b) Parasites - Common fungal

	parasites of plants, humans, insects and nematodes. Endovectors(c) Saprophytes - Fungal decomposition of organic matter, coprophilous fungi, cellulolytic fungi, lignolytic fungi. Fungi agriculture, nutraceautical, pharmaceuticals and biomedical applications. Fungi as model organism.
4.	**Lichens:** Nature of the relationship between algae and fungi - Habit and habitat – Classification. Ultra structure of lichen thallus – Internal structure – Special structures: Clyphellae, Cephalodia, Soredia, Isidia and Rhizinae. Reproduction: Asexual reproduction- Fragmentation, Isidia and Soredia, Sexual reproduction – Apothecia of lichen. Economic importance of lichens. Lichen as Air pollution indicators. Lichen in geomorphological and pedagogical studies.
5.	**Bryophytes:**Schuter's classification of Liverworts and Reimer's classification of mosses [In brief, general characters up to class level only]. Origin of Bryophytes including fossil evidence - Morphological variations, Anatomical and Cytological studies of Gametophytes and Sporophytes, Dehiscence of capsule and dispersal of spores. Evolution of gametophytes and sporophytes. Affinities of Bryophytes. Progressive sterilization of the sporogenous tissue. Ecology of bryophytes (Pollution indicators and monitoring). Economic importance of Bryophytes.
S. No.	**Laboratory/Practical**
1.	**Algae:** Study of the morphology and internal structure of the algae with particular reference to the following forms.*Cyanophyta: Oscillatoria, Lyngbya, Nostoc, Stigonema***,** *Rhodophyta: Polysiphonia, Gracilaria, Amphiroa***,** *Chlorophyta: Chlamydomonas, Chlorella, Zygnema, Oedogonium, Cladophora, Coleochaete, Bulbochaete, Neomeris, Ulva, Enteromorpha, Codium, Halimeda, Caulerpa, Charophyceae: Chara***,** *Xanthophyceae: Vaucheria/ Botrydium, Phaeophyceae: Ectocarpus, Dictyota, Padina, Turbinaria, Sargassum.Bacillarophyceae (one species of* Pinnale-*Amphora*and centrale-*Thalassiosira)*
2.	**Fungi:** Study the morphological and anatomical details of vegetative/reproductive structure for identification of the following: *Mucor, Pythium, Phytophthora, Rhizopus, Albugo, Pilobolus, Aspergillus, Penicillium, Saccharomyces, Neurospora, Xylaria, Peziza, Morchella, Agaricus, Polyporus, Lycoperdon, Cyathus, Fusarium, Alternaria, Puccinia.*
3.	**Lichens:** Usnea, Parmeliathallus and Lichen Apothecium for sectioning.
4.	**Bryophytes:** Study of Morphology and anatomy of the following: *Riccia,Anthoceros, Porella, Lunularia, Dumortiera, Asterella,Pallavicinia, Riccardia, Sphagnum, Funaria, Polytrichum , Plagiochasma, Targionia*.

Text books

Algae

1. Lee,R.E. 2009. Phycology ,Cambridge University Press.
2. Barsanti, L. and P. Gualtieri. 2006. Algae: Anatomy, Biochemistry, and Biotechnology ,CRC Press Taylor & Francis Group.
3. Sharma, O.P. 2008. Textbook of Algae, Tata McGraw Hill
4. Round, F.E.1986. The Biology of Algae. Cambridge University Press, Cambridge.
5. Bell, P.R. and Alan R. Hemsley. 2000. Green Plants: Their Origin and Diversity, Cambridge University press.

Fungi

1. Webster, J and R. Weber. 2007. Introduction to Fungi. 2007. by, 3rd Edition, Cambridge University press.

2. Alexopoulos, C.J., Blackwell, M and Mims C. W. 1996. Introductory Mycology, Acedemic Press, New York,
3. Deacon J. 2006. Fungal Biology, Blackwell Publishing.
4. Sharma K. 2007. Manual of microbiology: Tools and techniques, Anshan Ltd.
5. Ainsworth, G.C., Sparrow KF, Sussman AS. 1973. The fungi: An advanced treatise, Acedemic Press, New York

Lichen & Bryophytes

1. Purvis,W. 2000. Lichens. Smithsonian Institution Press.
2. Nash, T.H. 2008. Lichen Biology. Cambridge University Press, UK
3. Rashid, A. 1998. An Introduction of Bryophytes. Vikas publishing house Pvt. Ltd.
4. Watson, E.V. 1971. The structure and life of Bryophytes. Hutchinson and Co., London. .
5. Chopra, R.N. and Kumar, P.K. 1988. Biology of bryophytes. New Age International Publishers.

BTY 5102	**PLANT DIVERSITY II (Pteridophytes, gymnosperms and palaeobotany)** (Credits 4; Theory 3 hrs; Practical 3 hrs)
AIM	To study the various groups of Pteridophytes, Gymnosperms and Paleobotany
Objectives	• To educate about the various higher group of plants • To compare the similarities and differences in these groups and understand the phylogenetic relationships between them
Learning outcome	Students would ➢ Be able to identify these groups of plants in the field Have clear understanding about the ecological and economic value of these group of plants ➢ Have clear idea about concepts and practices in paleobotany
S.No	**Theory**
1.	**Pteridophytes:** Classification (Smith GM) of Pteridophytes – Salient features and comparative account of Psilopsida, Lycopsida, Sphenopsida and Pteropsida. Origin of first land plants: Telome theory; Origin of Leaves; sporophylls; roots; Stelar evolution in Pteridophytes
2.	**Experimental work on Pteridophytes:** Sexuality of Equisetum, Sexuality of homosporous ferns, regulatory role of light, hormonal control of antheridial differentiation and archegonial differentiation. Experimental studies on the development of gametophyte, regeneration of gametophyte. Heterospory and seed habit. Economic importance of Pteridophytes.
3.	**Gymnosperms:** Classification of Gymnosperms (KR Sporne). General characters and salient features of the following orders: Pteridospermales, Pentoxylales, cycadeles, coniferales, Taxales, Ginkgoales and Gnetales.
4.	Affinities of Gymnosperms, Comparative account of important characters of Cycas and Pinus. Comparative account of important characters of Gnetum and Ephedra. Primary and secondary structure of wood in coniferales. Organization of male and female cones. Economic importance.
5.	**Palaeobotany:** Definition of fossil, process of fossilization, types of fossils on the basis of their preservation; Fossil fuel, concept of Form Genus. Age of the earth, Geologic Time Scale, major events of plant life through geologic time. A detailed study of external, internal morphology and reproduction in the following fossils – *AsteroxylonMackiei*, *Lepidocarponlomaxi* and *Lyginopterisoldhamia*. Dr. BirbalSahni's contribution in Paleobotany.
S. No.	**Laboratory/Practical**

1.	**Pteridophytes:** Study of morphology, anatomy and reproductive structures of Psilotum, Lycopodium, Selaginella, Equisetum, Lygodium, Gleichenia, Pteris, Ophioglossum, Isoetes, Ceratopteris, Marsilea.
2.	**Gymnosperms:** Study of morphology, anatomy and reproductive structures of Cycas, Ginkgo, Cedars, Araucaria, Podocarpus, Ephedra, Pinus and Gnetum
3.	**Palaeobotany:** Study of important fossil forms from slides and specimens.

Text Books:

1. Bajaj, Y. P. S. 1989. Biotechnology in Agriculture and Forestry. Trees. Vol. II. Springer Verlag. Berlin, Hiedelberg.
2. Bhatnagar, SP and Moitra, A. 1996. Gymnosperms. New Age International (Pvt.) Ltd., New Delhi.
3. Chamber Lain, C.J. 2009. Gymnosperms Structure and Evolution. CBS Publishers and Distributors, New Delhi.
4. Moitra, A. 2003. Gymnosperms. New Age International (Pvt.) Ltd. New Delhi.
5. Parihar, NS. 1996. Biology and Morphology of Pteridophytes. Central Book Depot, Allahabad.
6. Purohit and Vyas. 1997. A Text Book of Gymnosperms. Ramesh Book Depot, Jaipur.
7. Rashid, A., 2002. An Introduction to Pteridophyta, 2nd Edition, Vikas Publishing, New Delhi
8. Sambamurty, A.V.S.S. 2005. A Text book of Bryophytes, Pteridophytes, Gymnosperms and Paleobotany. I.K. International Pvt. Ltd. New Delhi.
9. Sharma, OP. 1990. Text Book of Pteridophyta. McMillan India Ltd., New Delhi.
10. Singh, H. 1978. Embryology of Gymnosperms. Encyclopaedia of Plant Anatomy X. GebruderBortraeger, Berlin.
11. Smith, GM. 1971. Cryptogamic Botany, Vol. II Bryophytes and Pteridophytes. Tata McGraw Hill Publishing Co., New Delhi.
12. Sporne, K.K. 1991. The Morphology of Pteridophytes. B.I. Publishing Pvt.Ltd. Bombay.
13. Sporne, K.R. 1974. Morphology of Gymnosperms. Hytchnson Univ. Library. London.
14. Stewart, WN and Rathwell, GW. 1993. Paleobotany and the Evolution of plants. Cambridge University Press, Cambridge.
15. Trivedi, PC; Sharma, N; Dhanker, RS and Gupta, S. 2003. Diversity of Microbes and Cryptogams. Ramesh Book Depot, Jaipur.
16. Vasishta, BR., A.K. Sinha, and Anil Kumar, 2005. Pteridophyta. S. Chand and co. Ltd. New Delhi.
17. Vasishtha, PC. 2004. Gymnosperms Vol.V. S. Chand and Co., New Delhi.

BTY 5103	**ECOLOGY OF PLANTS**(Credits 4; Theory 3 hrs; Practical 3 hrs)
Aim	This course will introduce students to the major concepts and issues related to ecology of plants.
Objective (s)	In this course, • To educate on the factors affecting distribution and abundance of plant species • To understand the interactions between plants and its biotic as well as abiotic environment. • To understandthe issues related to large-scale ecology and global climate change.
Learning outcome	At the end of this course, students will have the ability: ➢ To explain the processes that are responsible for species distribution and abundance. ➢ To comprehend interactions between species and the environment responsible for community composition and structure. ➢ To apply ecological principles to current conservation issues.
S. No.	**Theory**

1.	**Introduction:** Definitions and concepts, Studying ecology at different levels i.e. Individuals, Population, Community, Ecosystem and Global level.
2.	**The individual plants and their environment:** Physical factors affecting the survival and reproduction of individual organisms; such at temperature, water, light, seasonality, soil nutrient composition, below ground interactions (Mycorrhizae).
3.	**Populations and evolution:** Population structure, growth and decline: Issues in the study of plant population growth, population structure, population growth and decline Evolutionary processes and outcomes: Natural selection, heritability, patterns of adaptation, levels of selection, other evolutionary processes affecting variation, variations among populations, ecotypes, and speciation. Growth and Reproduction ofIndividuals: Plant growth, ecology of growth, plant reproduction, pollination ecology, ecology of fruits and seeds. Plant life histories: Size and number of seeds, life history strategies.
4.	**Communities and their causes:** Community properties: Controversies and modern perspectives on communities, description of communities (species richness, diversity, evenness, and dominance, sampling methods and parameters for describing, community, composition, physiognomy, long-term studies). Interactions among plants: Competition at the level of individuals, experimental methods for studying competition, from interspecific competition to allelopathyto facilitation, modeling competition and coexistence, effects of competition on species coexistence and community composition, competition along environmental gradients. Herbivory and plant-pathogen interactions: Herbivory at the level of individuals, herbivory and plant populations, effects of herbivory at the community level, plant defenses against herbivory, parasitic plants, plant-pathogen interactions. Disturbance and Succession: Theories of the mechanisms and models of succession, disturbance, colonization, determining the nature of succession, primary succession, climax concept. Local abundance, diversity and rarity: Dominance, rarity and commonness, invasive species and community susceptibility to invasion, abundance and community structure, diversity and stability.
5.	**Paleoecology:**Srvey of several geological eras and periods especially those that represent significant times of change for plant communities, long-term changes in plant communities, and the scientific methods used for understanding them, and some of their implications.
6.	**Biomes:** Biomes of the world: Terrestrial, marine and fresh water biomes-Salient features and anthropological effects on different biomes. Biomes of India – Case studies of terrestrial (forest, grassland) and aquatic (fresh water, marine, estuarine) ecosystems
7.	**Ecosystems ecology:** Structure and function of ecological system-Trophic Levels and energy dynamics; Terrestrial/Aquatic Primary Production : Factors affecting Primary Production; Nutrients Cyclingand Retention
8.	**Large Scale Ecology:** Landscape Ecology: Landscape structure and Processes, Geographic Ecology: Isolation and Species Richness; Sampling Area and Number of species, Island Area and Species Richness, Island Isolation and Species richness, Theory of Island Biogeography; Equilibrium model of Island Biogeography, Concept of Metapopulation theory Global Ecology: Atmospheric Envelope and Greenhouse effect, Gobal element cycle and Human influence on element cycles, Land Cover and

	Atmospheric Composition; Global Positioning Systems, Remote Sensing and Geographical Information Systems in Large Scale Ecology.
9.	**Global aspects of plant ecology:** Environmental ethics, Values and world views; Influence of human activities on biodiversity and carbon budget, Global Climate change and institutions involved in it, Socioeconomic interactions. Sustainable living- a plan of action.
S. No	**Laboratory/Practical/Field Work**
1.	Experiments to be conducted include- Study of natural populations of plants in their native environment and in the secondary environments as well.
2.	Study of species richness, species abundance, and rarity.
3.	Study of disturbance and Succession Patterns.
4.	Study of Forest and Tree Vegetation using various methods.
5.	Study the adaptations in the plants to environment: To Drought, Salinity, Water Logging etc.
6.	Study of plant life history strategies: r-k selected species.
7.	Study of Predator-prey interactions and other plant-animal interactions.
8.	Study of seed dispersal strategies: High Investment and Low Investment models.

Text Books

1. Gotelli NJ. A Primer of Ecology. 2008. Sinauer Associates Publishers.
2. Grant WE and Swannack TM. 2008. Ecological Modeling: A common-sense approach to theory and practice. Blackwell Publishing.
3. Gurevitch J, Scheiner SM, Fox GA. 2002. The ecology of plants. Sinauer Associates Publishers.
4. Molles MC. 2008. Ecology: Concepts and Applications. The McGraw-Hill Companies, Inc.
5. Raven PH, Berg LR and Hassenzahl DM. 2010. Environment. John Wiley and Sons Inc.
6. Schulze ED, Beck E and Hohenstein KM. 2002. Plant Ecology. Springer-Verlag Heidelberg New York.
7. Stiling P. 2012. Ecology: Global Insights and Investigations. The McGraw-Hill Companies, Inc.
8. Latest research articles/review articles will be provided to the students by the concerned faculty.

BTY 5104	**GENETICS**(Credits 4; Theory 4 hrs; Practical 3 hrs)
Aim	To study the concepts in genetics
Objectives	• To study the basic classical Mendelian genetics and its deviations • Understanding chromosomal basis of inheritance and its application in linkage, mapping and cytogenetics • To studythe new emerging concepts in genetics and heredity • To studygenetics of a population
Learning outcome	After the completion of this course, the learner will have ➢ Knowledge on the principles of genetics and different types of heritable traits ➢ Knowledge on the mechanism of extra chromosomal and epigenetic inheritance. ➢ The ability to applythe knowledge to understand various traits in individuals and populations of microbes, plants and animals.
	Theory

1.	**Principles of heredity:** Mendelian principles, laws of probability, binomial theorem, Chi- square analysis, pedigree analysis.
2.	**Deviations from Mendelian inheritance:** Incomplete Dominance, Codominance, Lethal Alleles, Hierarchy of Dominance, Multiple Alleles, Pleiotropy, Polygenic inheritance, Quantitative trait loci (QTL), Statistics of quantitative genetics, Test for allelism, Environmental effect, Penetrance, Expressivity, Epistasis.
3.	**Chromosomal Basis of Inheritance:** Chromosomal theory of inheritance, Sex-linked traits, Pedigree analysis of linked traits, Activation and inactivation of X-chromosome, Sex-influenced traits, Sex-limited traits, Sex Determination.
4.	**Cytogenetics:** Eukaryotic chromosomes-structure, classification and organization, Banding, karyotyping, Molecular Cytogenetics (FISH, GISH, FIBER-FISH, Flow Cytogenetics, Flow karyotyping), Chromosomal aberrations.
5.	**Linkage and Mapping:** Linkage, Crossing over, Evolutionary significance of recombination, Two-point test cross, Three-point test cross, Genetic Mapping, Genetic mapping in Drosophila, Linkage and mapping using tetrads, Physical mapping, Application of mapping.
6.	**Extra chromosomal inheritance:** Cytoplasmic inheritance, Mitochondrial DNA, interplay between mitochondria and nuclear gene products, Chloroplast DNA, chloroplast biogenesis, Origin and evolution of mitochondria and chloroplast, Maternal effect.
7.	**Introduction to Epigenetic inheritance:** Epigenetic inheritance, Genomic Imprinting and Anticipation.
8.	**Population genetics:** Migration, mutation, selection, genetic drift, Estimating allele frequency, Nonrandom mating and genotype frequency, evolution of genomes, Inbreeding and co-ancestry.
S. No.	**Laboratory/ Practical**
1.	Karyotyping
2.	Working out on problems related to concerned topics such as 1. Classical genetics 2. Probability 3. Deviations from Mendelian genetics 4. Polygenic inheritance 5. Multiple Alleles 6. Chi- square analysis 7. Pedigree analysis 8. Sex-linked traits 9. Gene mapping 10. Allele frequency 11. Population genetics

Text Books:

1. Snustad PD, Simmons MJ. 2015. Principles of Genetics, 7th edition. Wiley.
2. Klug WS, Cummings MR, Spencer CA, Palladino MA, Darrell Killian. 2018. Concepts of Genetics, 12th edition. Pearson.
3. Griffiths AJF, Wessler SR, Carroll SB, Doebley J. 2015. Introduction to Genetic Analysis, 11th edition. W.H. Freeman & Worth Publishers.
4. Pierce BA. 2016. Genetics: A Conceptual Approach 6th edition. W. H. Freeman.
5. Hartwell L, Goldberg ML, Fischer J, Hood L. 2017. Genetics: From Genes to Genomes 6th edition. McGraw-Hill Education.

6. Hartl DL and Jones EW. 2011. Genetics: Analysis of Genes and Genomes, 7th edition. USA: Jones and Barlett Publishers.
7. Mathew PM. Fundamentals of population genetics with emphasis on human inbreedings, 1st edition. Southern book star.
8. Strickberger MW. 2015. Genetics, 3rd edition. Pearson.
9. Samuels ML, Witmer JA, Schaffner A. 2015. Statistics for the Life Sciences, 5th edition. Pearson.
10. Brooker R. 2017. Genetics: Analysis and Principles, 5th edition. McGraw-Hill Higher Education
11. Tamarin R, 7th edition. 2017. Principles of Genetics. McGraw Hill Education.
12. Elrod S, Stansfield W. 2010. Schaum's Outline of Genetics, 5th edition. McGraw-Hill Education.
13. Hartl DL, Clark AG. 2006. Principles of Population Genetics 4th edition. Sinauer Associates is an imprint of Oxford University Press.
14. Crow JF, Kimura M. 2009. An Introduction to Population Genetics Theory. The Blackburn Press.
15. Hedrick PW. 2010. Genetics of Populations, 4th edition. Jones & Bartlett Learning.

BTY 5105	**CELL AND MOLECULAR BIOLOGY** (Credits 4; Theory 4 hrs; Practical 3 hrs)
Aim	To study about the organization of cell and the molecules of heredity
Objectives	• To study about cell and its components • To understand the metabolism of various nucleic acids • To understand how genes are expressed and regulated • To study the basic techniques involved in cell and molecular biology
Learning outcome	After the completion of this course, the learner will ➢ Understand structural components of cell and molecularbasis for the transmission of hereditary traits ➢ Know how genes are expressed and regulated in organisms ➢ Will have the practical skills in basic cell and molecular biology techniques.
	Theory
1.	**Cell Biology:** Cell structure in eukaryotes and prokaryotes, cell organelles and their ultra-structure, functions, cytoskeleton, cytoplasmic streaming and cell adhesion, Cell communication: junctions between cells and cell signaling, Cell membranes: membrane dynamics and solute transport across membranes.
2.	**Structural organization of chromosomes:** Structural organization of chromosomes in Prokaryotes and Eukaryotes. Structural hierarchy of chromosomes. Centromeres and telomeres.
3.	**Cell Division:** Cell cycle and Regulation.
4.	**Nucleic acids:** Structural organization of genetic material in Prokaryotes and Eukaryotes. Structure, composition and function of DNA and RNA.Different types of RNA- mRNA, tRNA, rRNA, snRNA, snoRNA, miRNA, XistRNA, siRNA,
5.	**Mechanism of DNA replication:** Mechanism of DNA replication, DNA polymerase I, II, III, DNA gyrases, topoisomerases, ligases, initiation of replication, roles of RNA polymerase (primase) and replisome complex, current concept of DNA replication in prokaryotes and eukaryotes.
6.	**Gene expression:** The genetic code, one gene one enzyme, one gene-one polypeptide, Mutations and recombination within a gene, Experiments conducted to decipher the genetic code, salient features, exceptions. **Transcription -** General features of transcription, transcription unit, Current concepts of transcription in prokaryotes and eukaryotes, Regulatory sequences and transcription factors involved, Post-transcriptional modifications.

	Translation - Basic structure of proteins, ribosomes, tRNA. Wobble-hypothesis, Mechanism of translation and factors involved in prokaryotes and eukaryotes, factors affecting translation accuracy, non-ribosomal peptide synthesis.
7.	**Regulation of gene expression:** Regulation in prokaryotes - Constitutive, Inducible and Repressible expression, positive and negative control. Induction and catabolite repression in *lac* operon, repression and attenuation in *trp* operon, Translational and post translational regulation. Lysogenic and lytic switches in lambda phage. Regulation in Eukaryotes - Regulation at chromatin level, Epigenetic changes at chromosome level, genome imprinting, transcriptional gene regulation, epigenetic mechanisms of transcriptional gene regulation, regulation by *cis*-acting control elements, alternative promoters, trans-acting factors, transcriptional activator proteins, enhancers, silencers, post-transcriptional gene regulation including alternative splicing, RNA editing, RNA interference, Riboswitches, RNA stability, role of RNA-decaying factors in gene regulation, translational regulation, post-translational control, protein processing, proteosome complex and protein degradation.
S. No.	**Laboratory/ Practical**
1.	Media preparation for plasmid isolation.
2.	Raising *E. coli* with a plasmid, by streaking on antibiotic-containing media.
3.	Raising *E. coli* liquid culture for plasmid isolation.
4.	Plasmid DNA isolation using the alkaline lysis method.
5.	Gel electrophoresis to see the isolated plasmid, study the DNA staining procedure and alternative forms of plasmid obtained after extraction.
6.	Media preparation for plant DNA isolation.
7.	Plant genomic DNA isolation from plant tissues by CTAB method.
8.	Gel electrophoresis to see the isolated plant DNA.
9.	Plant RNA isolation
10.	Gel electrophoresis to see the isolated plant RNA.
11.	Quantification of DNA/RNA
12.	Exercises relevant to topics such as *lac* operon, *trp* operon, etc.

Text Books:

1. Watson JD, Tania AB, Stephen PB, Alexander G, Michael L, Richard L. 2017. Molecular Biology of the Gene, 7th edition. Pearson Education.
2. Krebs JE, Goldstein ES, Kilpatrick ST. 2017. Lewin's GENES XII. Jones and Bartlett Publishers, Inc.
3. Lodish H, Berk A, Kaiser CA, Krieger M, Bretscher A. 2016. Molecular Cell Biology, 8th edition. W H Freeman & Co.
4. Alberts B. 2014. Molecular Biology of the Cell, 6th edition. Garland Science.
5. Hartl DL, Cochrane B. 2017. Genetics: Analysis of Genes and Genomes 9thedition.Jones& Bartlett Learning.
6. Griffiths AJF, Wessler SR, Carroll SB, Doebley J. 2015. Introduction to Genetic Analysis, 11th edition .W.H. Freeman & Worth Publishers.
7. Griffiths AJF, Gelbart WM, Lewontin RC, Miller JH. 2002. Modern Genetic Analysis: Integrating Genes and Genomes 2nd edition. W. H. Freeman.
8. Stryer L, Berg JM, Tymoczko JL, Gatto GJ Jr.2019. Biochemistry 9th edition. W. H. Freeman.
9. Karp G, Iwasa J, Marshall W. 2015. Karp's Cell and Molecular Biology: Concepts and Experiments, 8th edition. Wiley.
10. Robertis De. 2010. Cell and Molecular Biology, 8th edition. Lippincott Williams & Wilkins.
11. Karp G. 2013. Cell Biology, 7th edition. Wiley.
12. Russell PJ. 2011. iGenetics: A Molecular Approach, 3rd edition. Pearson.

List of courses in Semester II

Semester	Course code	Course Title	Hours/week		Credit
			Lecture	Practical	
II	BTY 5206	Plant Biochemistry and Physiology	4	3	4
	BTY 5207	Developmental Biology of the Plants	3	3	4
	BTY 5208	Plant biotechnology and Plant genetic Engineering	4	3	4
	BTY 5209	Omics in Plant Science	4	3	4

BTY 5206	**PLANT BIOCHEMISTRY AND PHYSIOLOGY** (Credits 4; Theory 4 hrs; Practical 3 hrs)
AIM	This course aims to provide students an understanding of the core topics and advanced integrated knowledge in plant biochemistry and physiology.
Objectives	• To learn the structure and function of essential biomolecules and their key chemical and physical properties. • To understand the biochemical mechanisms underlying the metabolism of plants • To understand the biochemistry of value added products and secondary metabolites from plants.
Learning outcome	At the end of the course the students will ➢ Realize the structure of essential biomolecules and their key role in plants ➢ Understand the different pathway of plant anabolism and catabolism ➢ Acquire knowledge to generate useful products through biochemical engineering.
S.No.	**Theory**
1	**Basic concepts in Plant biochemistry and physiology:** Subcellular fractionation, biological membranes; Ionization of water- weak acids and weak bases; pH scale, Buffers; Thermodynamics in biochemistry; bulk movement of water and substances across the membrane, aquaporins, stomatal regulation of transpiration, anti transpirants; Nutrition in plants
2.	**Carbohydrate and Glycobiology:** Structure and classification- Monosaccharides, Oligosaccharides and polysaccharides; Biological functions, Glycoproteins, Proteoglycans; Metabolism: Glycolysis, TCA cycle, Pentose phosphate pathway, oxidative phosphorylation; Gluconeogenesis; Cyanide insensitive respiration; Anaerobic respiration. Sucrose synthesis and breakdown, starch structure and metabolism
3	**Plant cell wall polymers**: structure elucidation, Degradation, Cellulose, Hemicellulose, Pectin, Lignin; Plant biomass applications: Bioenergy; Value added products

4	**Amino acids, Peptides and Proteins**: Aminoacids and Peptides : Nomenclature, Structure, Classification, properties and Biological functions Proteins: Conformation-Tertiary and Quaternary; Protein synthesis; Protein folding; Post translational modifications; molecular chaperones; Proteolysis; Protein isolation from plant tissues, Purification, quantification protein- ligand interaction; Metabolism: Amino acid synthesis and catabolism.
5	**Enzymes:** Classification, principles of catalysis, Mechanism of enzyme activity, Factors affecting enzyme activity, regulation, Kinetics, Enzyme inhibition; Cofactors and Coenzymes
6	**Photosynthesis:**Light reaction- pigments, photosynthetic apparatus, photosynthetic electron transport, water oxidation and its molecular mechanism, photophosphorylation, pseudocyclic electron transport, Mehler reaction
7	**Dark reaction**: Carbon dioxide fixation in C3, C4 and CAM plants regulation of PCR cycle; photorespiration and its regulation, environmental factors affecting photosynthesis.
8	**Nitrogen metabolism**: Nitrogen nutrition, organic nitrogen, nitrogen fixation in legumes, nitrate and ammonia assimilation: Sulfur metabolism Inter relationship between photosynthesis, respiration and nitrogen metabolism
9	**Nucleotides and Nucleic acids:** Functions of nucleotides, nucleotide biosynthesis by de novo pathways and salvage pathways; Purine and Pyrimidine metabolism
10	**Lipids:** Classification of lipids; Occurrence and properties of fatty acids, Fatty acid metabolism; Glycolipid, Lipid biosynthesis: membrane phospholipids, triacylglycerols, cholestrol, steroids and Isoprenoids.
11	**Growth and development**: Plant growth regulators- Phytohormones- Auxin; cytokinin; Gibberellins; ethylene; ABA. polyamines; brassinosteroids, jasmonate; Phytochromes and light control; physiology of flowering and fruiting; Seed dormancy and germination, senescence; Plant movements
12	**Stress physiology**: Abiotic and biotic stresses, morphological and cellular adaptation; molecular mechanism of stress tolerance and protection
13	**Plant secondary metabolites:** Classification; Isolation, Characterization**,** Biosyntheticpathways, Applications (Alkaloids,Phenols,Terpenoids,Flavanoids) ; Allelopathic substances

S.No	**Laboratory/Practical**
1	Quantitative estimation of reducing sugar
2.	Quantitative estimation of protein.
3.	Isolation of enzyme (amylase/ xylanase) from germinating finger millet seeds and estimating crude enzyme activity.
4	Isolation of enzyme (amylase/ xylanase) from germinating finger millet seeds and estimating crude enzyme activity.
5	Cell wall profiling (hemicellulose composition/hydroxycinnamate) by HPLC
6	Enzyme kinetics- Determination of pH and temperature optimum, Michaelis constant (Km) and Vmax.
7	Estimation of total phenolics
8	Estimation of cell wall polysaccharide, cellulose, in selected grass species.
9	Isolation of intact organelles: chloroplasts and mitochondria.
10	Chlorophyll estimation
11	Assay of photosynthetic electron transport activity from isolated chloroplast using oxygraph
12	Determination of ascorbic acid content of tissue.

Text Books:

1. Buchanan BB, Gruissem W, Jones RL 2000. Biochemistry and molecular biology of plants. L K International Pvt. Ltd.
2. Nelson DL, Michael M coxe: 2008. Lehninger Principles of Biochemistry fifth edition, W. H. Freeman and Company
3. Nelson DL, Michael M coxe 2016. Lehninger Principles of Biochemistry: seventh edition, W. H. Freeman and Company
4. TAIZ L and ZEIGER E. 2010 Plant Physiology. (5th Edition). Sinauer Associates, Inc., Sunderland, Massachusetts. ISBN: 978-0-87893-866-7.
5. Dey PM and Harborne J B. 1997. Plant Biochemistry. first edition, Academic Press
6. Bonner J and Warner JE. 1976. Plant Biochemistry: Third edition,Academic press
7. Heldt HW and Piechulla B 2011. Plant Biochemistry:fourthedition,Academic Press
8. Nobel PS and Henry RJ 1996. Practical application of Plant MolecularBiology. Chapman and Hall, London 9
9. Wink M 1999. Biochemistry of Plant Secondary Metabolism: Sheffield Academic Press,Volume 2
10. Dey PM and Harborne JB. 1997. Plant Biochemistry. Academic Press
11. Ekinci D. 2012. Biochemistry**,** volume 8,In tech
12. Finkelstein A. 1987. Water movement through lipid bilayers, pores and plasma membranes: Theory and reality. Wiley, New York
13. Mengel, K. and Kirkby E.A. 1996. Principles of Plant Nutrition, Panama Publishing Corporation, New Delhi, India,

BTY 5207	**DEVELOPMENTAL BIOLOGY OF THE PLANTS** (Credits 4; Theory 3 hrs; Practical 3 hrs)
Aim	Aim of this course is to introduce students to the cellular and molecular processes that govern plant development.
Objective(s)	Main objectives of this course are to: • Make students familiar with the molecular and cellular basis of the processes that govern plant development. • Expose students to the most recent scientific advances in plant development. • Make students familiar with tools and methodologies commonly used in plant cell and developmental biology research.
Learning outcome	At the end of this course students will be able to: ➢ Approach complex biological questions related to developmental biology of plants. ➢ Understand the evolutionary significance of seed development and functions ➢ Have practical skills to do basic developmental biology experiments.
S. No.	**Theory**
1.	**Introduction to developmental biology of plants:**Introduction to model plants used for development studies in plant system, advantages of each system with special emphasis on model plant Arabidopsis
2.	**Basics:** Cell division and cell cycle, planes of cell division, cell autonomy, cell polarity, radial a/symmetry, pattern formation, abaxial/adaxial identity, cell lineage vs. cell position, meristem, determinant vs. indeterminant meristem.
3.	**Reproduction:** Male and female gametophyte development, genetic and hormonal regulation of reproduction, pollination and fertilization.
4.	**Seed development and germination:** Seed formation, cotyledon, endosperm and seed coat development. Seed dormancy and germination, hormonal

	regulation of seed dormancy, seedling development, Concept of vernalization and genetic regulation of vernalization.
5.	**Embryogenesis:** Basic lay out of dicot and monocot embryos, stages of embryodevelopment, embryonic axis, cell division and pattern formation in embryo,genetic and hormonal regulation of embryo development, cell polarity in embryo.
6.	**Shoot development:** Structure and function of shoot apical meristem (SAM), initiation and maintenance of SAM, regulation of meristem size, antagonism between SAM and lateral organs, genetic regulations, axial bud formation, shoot branching.
7.	**Leaf development:** Emergence of leaf primordium from SAM, abaxial and adaxial identity of leaf cells, leaf margin, trichrome, epidermis and stomatal development, theories of stomatal development, vascular differentiation.
8.	**Floral development:** Transition from vegetative to reproductive stage, inflorescence meristem, floral whorls specification, ABC model and beyond, whorl boundary specification, asymmetric flower development, structure and development of monocot flowers.
9.	**Fruit Development and ripening:** Genetics and epigenetics of ovary to fruit transition, role of hormones in regulation of ovary to fruit transition, fruit size genes and the control of fruit size in model crops such as Arabidopsis, Tomato, ripening of climacteric and non-climacteric fruits; Various factors controlling fruit ripening, role of hormones in fruit ripening. Manipulation of fruit ripening by altering various parameters. Endoreduplication and the fruit development.
10.	**Experiments in developmental biology:** Cell ablation technique, temporal and spatial expression of genes, in situ hybridization, interacting genes and their position in respect to signalling pathway, and targeted mutagenesis in plants, mutant generation and identification of the genes, Use of in vitro system for studying plant development.
S. No.	**Laboratory/Practical**
1.	Practical in this course will include; study of model plants, stages of male and female gametophyte development.
2.	Pollen load and viability.
3.	Seed germination and development under different controlled environmental regimes.
4.	Apical meristem, stomatal development (various ontogenic mechanisms),
5.	Stages of fruit development and ripening etc.
6.	Manipulation of various factors for study of different developmental processes.
7.	Studying plant development under various treatments (temperature, water logging, different light regimes etc.)

Text Books:

1. Bhojwani SS &Bhatnagar SP. 2009. Embryology of angiosperms. Vikas Publication House.
2. Buchanan BB, Grussem W and Jones RL. 2015. Biochemistry and Molecular Biology of plants. John Wiley & Sons Inc.
3. Davis PJ. 2004. Plant hormones: Biosynthesis, Signal Transduction, Action. Kluwer Academic Publishers.
4. Raghavan V. 1997. Molecular Embryology of Angiosperms. Cambridge University Press.
5. Raghavan V. 2000. Developmental Biology of the Plants. Springer-Verlag New York.
6. Raghavan V. 2006. Double Fertilization: Embryo and Endosperm Development in Flowering Plants. Springer-Verlag Berlin Heidelberg.
7. Seymour GB, Tucker GA, Poole M &Giovannoni J. 2013. The Molecular Biology and Biochemistry of Fruit Ripening. A John Wiley & Sons, Inc., Publication.

8. Srivastava LM. 2002. Plant Growth and Development: Hormones and Environment. Academic Press.
9. Taiz L and Zeiger E, Moller IM & Murphy A. 2015. Plant Physiology & Development. Sinauer Associate Inc. Publishers.
10. Taiz L and Zeiger E. 2013. Plant Physiology. Sinauer Associate Inc. Publishers.
11. The Arabidopsis Book, ASPB publication (available freely at www.aspb.org)
12. Latest research articles/review articles will be provided to the students by the concerned faculty.

BTY 5208	**PLANT BIOTECHNOLOGY AND PLANT GENETIC ENGINEERING** (Credits 4; Theory 4 hrs; Practical 3 hrs)
Aim	To study recombinant DNA (rDNA) technology and plant genetic engineering and, their application in plant biotechnology
Objectives	• To Study about various vectors and DNA modifying enzymes used in rDNA technology • To understand the methodsand applications of plant biotechnology • To study the biosafety methods, laws, ethical issues of rDNA technology and IPR
Learning outcome	After the completion of this course, the learner will know ➢ How to utilize plants forbiotechnology application ➢ Understand the principles of rDNA technology and how it can be used in plants to generate better traits ➢ Understand biosafety, legal and ethical issues of genetic engineering in plants.
S.No.	**Theory**
1.	**Vectors in molecular cloning:** Plasmids, phages, phagemids, hybrid vectors, cosmids, eukaryotic virus-based vectors, shuttle vectors, expression vectors (especially plant expression vectors), fosmids, PACs, BACs and YACs.
2.	**Molecular cloning:** Steps - amplification, restriction digestion, ligation, transformation, screening. Special molecules and enzymes for DNA modifications - restriction enzymes, ligases, klenow, phosphatases, recombinases, modification of DNA fragments using linkers, adaptors and homopolymer tailing. Recombination based cloning.
3.	**Introducing genes into prokaryotes:** Transformation, transduction, conjugation, electroporation.
4.	**Identifying the right clone:** Screening and selection - reporter genes, selectable markers, insertional inactivation of marker genes. Molecular screening - PCR, colony and dot-blot hybridization, nucleic acid hybridization and immunological techniques.
5.	**Applications of rDNA technology in biotechnology:** Genomic and cDNA libraries, isolation of important genes, Construction of gene cassette, protein engineering, bioprocessing, phytoremediation, agriculture.
6.	**Gene transfer to plants:** Tissue culture in plant genetic engineering Integrative DNA transfer - direct transformation methods, *Agrobacterium*-based methods, Organelle engineering. Non-integrative DNA transfer - Plant viruses and Protoplast fusion.

	Molecular and functional analysis of transgenic plants.
7.	**Biotechnological applications of plant genetic engineering:** Functional genomics, resistance to abiotic and biotic stresses, crop quality improvement, nutrient enhancement, nitrogen fixation, nutrition up-take, production of male sterile lines, plantibodies, vaccines, commercial oils, plant secondary products, biofuel, bioplastics and plants as bioreactors.
8.	**Hazards and impact of GMOs:** Biosafety considerations, Biosafety regulations in India. Ethical issues, biological risks, impact on biodiversity, controlled trials. Economic issues, legal issues, intellectual property rights (IPR) in relation to plant biotechnology.
S. No.	**Laboratory/Practical**
1.	Plasmid restriction digestion and gel electrophoresis to study DNA mobility, stoichiometry, deciding factors for percentage of agarose/polyacrylamide, importance of DNA marker, band size calculation, etc.
2.	Isolation of vector plasmid and, plasmid with insert/ or PCR product, for cloning
3.	Preparation of vector and insert by restriction digestion and elution, for cloning
4.	Ligation for cloning
5.	Preparation of competent cells and transformation
6.	Working out problems on how to calculate restriction-digested band size and construction of to-the-scale plasmid map
7.	*Agrobacterium*-mediated plant transformation – preincubation
8.	*Agrobacterium*-mediated plant transformation – infection
9.	*Agrobacterium*-mediated plant transformation – selection
10.	GUS or GFP detection
11.	Gene amplification using PCR and its confirmation using gel electrophoresis
12.	Southern blotting and transfer

Text Books:

1. Primrose SB, Twyman R. 2016. Principles of Gene Manipulation and Genomics, 8th edition. Wiley-Blackwell.
2. Brown TA. 2016. Gene Cloning and DNA Analysis: An Introduction, 7th edition. Wiley-Blackwell.
3. Cooper G. 2018. The Cell: A Molecular Approach, 8th edition. Sinauer Associates.
4. Glick BR, Patten CL. 2017. Molecular Biotechnology: Principles and Applications of Recombinant DNA, 5th edition. ASM Press.
5. Bourgaize D, Jewell TR, Buiser RG. 1999. Biotechnology: Demystifying the Concepts, 1st edition. Benjamin Cummings.
6. Nicholl DST. 2008. An Introduction to Genetic Engineering, 3rd edition. Cambridge University Press.
7. Gelvin SB, Schilperoort RA. (Eds.). 2000. Plant Molecular Biology Manual. Springer.
8. Clark, Melody S. (Eds.). 1997. Plant Molecular Biology — A Laboratory Manual. Springer.
9. Dale JW, Schantz MV, Plant N. 2011. From Genes to Genomes: Concepts and Applications of DNA Technology, 3rd edition. Wiley.
10. Shah JM. 2012. Strategies to overcome fungal diseases in plants: An enchiridion. Lambert Academic Publishing AG & Co.
11. Kshitij Kumar Singh. 2015. Biotechnology and Intellectual Property Rights: Legal and Social Implications. Springer.
12. Erbisch FH, Maredia K (Eds.). 2003. Intellectual Property Rights in Agricultural Biotechnology, 2nd edition. CABI Publishing.
13. Parashar S, Goel D. 2013. IPR, Biosafety and Bioethics. Pearson India.

BTY 5209	**OMICS IN PLANT SCIENCE** (Credits 4; Theory 4 hrs; Practical 3 hrs)
Aim	To educate post graduate students on the omic methods and their applications in plant science
Objectives	• To learn the different omic methods to study plant genome and its functions.To learn the different applications of the omic methods. • To learn how to integrate different methods to understand plant systems.
Learning outcome	After completion of this course the students will ➢ Know the different omic methods and their applications ➢ How these methods can be used to answer critical research questions in Plant Biology ➢ Have the basic idea on different softwares and techniques used for high throughput data analysis.
S. No.	**Theory**
1.	**Introduction to 'omics':** Introduction to Genomics, Transcriptomics, Protemomics, Metabolomics and single cell genomics
2.	**Genomics:** Genome sequencing, Whole genome shotgun sequencing, Physical mapping of genomes, Clone-by-clone sequencing, In silico methods for Data Management, New generation sequencing technologies, Bioinformatics tools to analyse genomes, Examples of sequenced genomes (yeast, Arabidopsis and rice), Applications of structural genomics. Structural genomics, functional genomics, Epigenomics, Comparative genomics, Phylogenomics.
3.	**Epigenomics:** Whole-genome bisulfite sequencing, epigenetic marks and gene regulation, genomics approaches to studying epigenetics and methods to manipulate epigenome.
4.	**Structural genomics:** Major features of plant genomes - Organization, size, diversity, transposable elements, microsatellites and other repetitive DNA, gene density, colinearity, plant genome size variation, genome size expansion and contraction.
5.	**Metagenomics:** Sources of metagenomes, making of libraries of DNA, cDNA, rRNA etc. for microbial diversity analysis, Applications of metagenomics.
6.	**Plant Functional genomics:** T-DNA mutagenesis, Transposon tagging, Gene traps, enhancer traps, Gain of function approaches, Gene over expression and T- DNA activation tagging, Gene discovery using inverse PCR, plasmid rescue and TAIL-PCR methods, Chemical mutagenesis and High-throughput TILLING, Physical mutagenesis, Gene silencing methods using RNAi, Targeted knockout of gene using Homologous recombination and, Genome editing using Zinc-finger Nucleases, TALENS, CRISPRs etc.
7.	**Transcriptomics:** Gene expression, EST contigs, cDNA libraries, macroarrays, microarrays, whole transcriptome sequencing, transcript profiling, sRNA sequencing (sRNA-seq), Applications of transcriptomics.
8.	**Proteomics:** Protein isolation and identification methods SDS -PAGE, Iso-electric focussing, 2D gel electrophoresis, Peptide sequencing, Mass Spectrometry methods used in proteomics, Peptide data bases, Immunological methods to study protein functions, Protein-protein and Protein-DNA interactions, Comparative proteomics, subcellular proteomics, quantitative proteomics
9.	**Metabolomics:** Metabolites and metabolome, Metabolite extraction, separation and detection, Mass Spectrometry methods used in metabolomics, Data bases for Metabolites.Applications of Metabolomics

10.	**Applications:** Integrated OMIC approaches to study plant biology, Agricultural applications, therapeutic application, Chloroplast genomics, Synthetic genomics etc.
S. No.	**Laboratory/Practical**
1.	Plant Genome Databases.
2.	Computational tools to explore plant genome.
3.	Small genome analysis
4.	Exercises relevant to the topics
5.	Transcriptome analysis

Tex Books:

1. Gideon Grafi and NirOhad. 2013. Epigenetic Memory and Control in Plants. Springer.
2. Jonathan Wendel, Johann Greilhuber, JaroslavDolezel, Ilia J. Leitch. 2012. Plant Genome Diversity. Springer.
3. Igor Kovalchuk, Franz J. Zemp. 2011. Plant Epigenetics: Methods and Protocols. Springer Protocols. Springer.
4. Nigel W. Hardy, Robert D. Hall. 2012. Plant Metabolomics: Methods and Protocols. Springer Protocols. Springer.
5. Xiaoquan Qi, Xiaoya Chen, Yulan Wang. 2014. Plant Metabolomics: Methods and Applications. Chemical Industry Press. Springer.
6. Diana Marco (Ed.). 2011. Metagenomics: Current Innovations and Future Trends. Horizon Scientific Press.
7. Arthur M. Lesk 2017 Introduction to genomics (3rd Edition)Oxford University Press
8. Paul S. Freemont and Richard Kitney (Ed). 2012 Synthetic Biology - a Primer (1st edition) Imperial college Press.
9. Daniel G. Gibson (Ed). (2017)Synthetic Biology: tools for engineering Biological systems.
   Cold Spring harbor laboratory Press.

List of courses in Semester III

Semester	Course code	Course Title	Hours/week		Credit
			Lecture	Practical	
III	BTY 5310	Plant Systematics	4	3	4
	BTY 5311	Economic Botany	3	3	4
	BTY 5312	Plant-Pathogen Interactions	3	3	4
	BTY 5313	Methods in Plant Biology	4	3	4

BTY 5310	**PLANT SYSTEMATICS** (Credits 3+1*=4; Theory 4 hrs; Practical 3 hrs) *Field study
Aim	The aim of this course is to introduce students with the important concepts of plant systematics exploring botanical diversity.
Objective(s)	The objectives of the course are: • To make students familiar with the foundations of plant systematics, methods used insystematic study.

	• To make students familiar with the concepts and the terminology used in plant systematics including modern molecular systematics. • To present the most recent knowledge of evolutionary relationships of plants as well as practical information vital to the field.
Learning outcome	After completing this course, students will be able to: ➢ Understand the principles of classical and molecular taxonomy. ➢ Identify and classify the plants by taxonomic criteria. ➢ Apply the systematic principles to study the evolution of the taxa.
S. No.	**Theory**
1.	**History of developments in taxonomy:** Systematics - concepts and components; Taxonomic literature - Floras, Monographs, Indices, Keys and Journals. Field and Herbarium Methods. Importance of Herbaria and Botanical gardens.
2.	**Classification of flowering plants:** Principles, Outlines, Merits and Demerits of Bentham and Hooker; Engler and Prantl; Hutchinson, and Takhtajan. Recent classification based on molecular systematics i.e. APG I to APG IV and recent updates, Merits and demerits of phylogenetic classification
3.	**Botanical nomenclature:** International code of Nomenclauture (ICN) for algae, fungi and Plants: General Principles, Typification, Principles of priority and their limitations - Effective and valid publication – Authors, Citations Retention, choice and rejection of names.
4.	**Taxonomic evidence:** Secondary metabolites, Anatomy, Embryology, Cytology, Polyploidy, palynology in relation to taxonomy. **Numerical methods in taxonomy:** Phenetics, Principal Component Analysis, Discriminant Analysis.
5.	**Molecular systematics:** The module deals with central concepts of molecular systematics, technologies for collection of molecular data and basic methods for phylogenetic analysis. **Phylogenetic systematics:** The principles, methodology, and applications of phylogenetic analyses includes taxon selection, character analysis (description, Character Selection, character state discreteness, character correlation, homology assessment, character state transformation series and polarity, character weighting, character step matrix, character × taxon matrix), cladogram construction (apomorphy, recency of common ancestry, monophyly, parsimony analysis, unrooted trees, polytomy, reticulation, taxon selection and polymorphic characters, outgroup comparison, ancestral versus derived characters, consensus trees, long branch attraction, maximum likelihood, bayesian analysis, measures of homoplasy, cladogram robustness) and cladogram analysis (phylogenetic classification, character evolution, biogeography and ecology, ontogeny and heterochrony). **Molecular data for phylogenetic analysis and identification:** Acquisition of molecular data, DNA sequence data (Polymerase Chain Reaction, DNA sequencing reaction, types of DNA sequence Data (nuclear DNA), chloroplast and mitochondrial DNA), analysis of DNA sequence data; DNA barcoding; Restriction Site Analysis (RFLPs), allozymes, microsatellite DNA, Random Amplified Polymorphic DNA (RAPDS), Amplified Fragment Length Polymorphism (AFLPs). **Plant introgressions, polyploidy, evolution and crop domestication.**
6.	**Study tour and submission of field report:** The students have to take up a mandatory field/study tour for 9 days covering the topics in core courses spread across three semesters (I, II and III). **The study tour program will be as follows:**

	1. One major field trip of not less than 5 days to study the taxonomy of the flora existing at different agro climatic conditions as well as for making herbaria and digital Album. **2.** The rest of the 4 days include one-day field/ study trips for studying the local flora in the marine, fresh water and hill environments and for preparing reports. After the tour taken up by students during the II semester, students are required to submit 5 herbaria, 25 digital photos with taxonomical and ecological information. In addition to this, Field/Study tour report is also to be submitted for evaluation.
S. No.	**Laboratory/Practical**
1.	Live plants/ Herbarium specimens of the following families will be provided in the class for description and identification (classification based on APG IV): Construction of floral diagrams, floral formula and Technical descriptions of the Species from the given families: 1. Ranunculaceae, 2. Lentibulariaceae, 3. Balasaminaceae, 4. Magnoliaceae 5. Guttiferae (Clusiaceae) 6. Malvaceae 7. Fabaceae 8. Caesalpiniaceae 9. Mimosaceae 10. Lythraceae 11. Melastomaceae 12. Cucurbitaceae 13. Apiaceae 14. Rubiaceae 15. Compositae (Asteraceae) 16. Apocynaceae 17. Boraginaceae 18. Convolvulaceae 19. Scrophulariaceae 20. Acanthaceae 21. Lamiaceae 22. Euphorbiaceae 23. Orchidaceae, 24. Poaceae, 25. Cyperaceae 26. Araceae
2.	Preparation of dichotomous keys, Phylogenetic analyses using PAUP. Study of the local flora by two to three classes.

Text Books:

1. APG III, 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Botanical Journal of the Linnean Society 161: 105 –121.
2. Barry G. Hall, 2007. Phylogenetic Trees Made Easy: A How-To Manual, Third Edition.Sinauer Associates, Inc., Publishers, Sunderland, USA.
3. Benson,L.D. 1962. Plant Taxonomy: Methods and Principles. Ronald Press, New York.
4. Cronquist, A. 1981. An Integrated System of Classification of Flowering Plants. Columbia University Press, New York.
5. Cracknell AP, Hayes L .2009. Introduction to Remote Sensing. CRC Press, Boca Raton, USA (Special Indian Edition).
6. Crawford DJ .2003. Plant Molecular Systematics. Cambridge University Press, Cambridge, UK.
7. Cronquist A .1981. An integrated system of classification of flowering plants. Columbia University Press, New York.
8. Davis, P.H. and V.M. Heywood. 1963. Principles of Angiosperm Taxonomy. Oliver and Boyd, Edinburgh.
9. Douglas E. Soltis, Pamela E. Soltis, Peter K. Endress, and Mark W. Chase, 2005. Phylogeny and Evolution of Angiosperms. Sinauer Associates, Inc., Publishers, Sunderland, USA.
10. Hollingsworth PM, Bateman RM and Gornall RJ (1999). Molecular systematics and Plant Evolution. Taylor and Francis, London.
11. Jones, S.B. and A.E. Luchsinger. 1987. Plant Systematics (2nd Ed.) McGrawHill Book Company. New York.
12. Judd WS, Campbell CS, Kellogg EA, Stevens PA and Donoghue MJ (2002) Plant Systematics: A Phylogenetic Approach. SinauerAssociaes, Inc., Massachusetts.
13. Lawrence, G.H.M. 1951. Taxonomy of Vascular. Plants. Oxford and IBH Publishing Co.
14. Michael George Simpson, 2006. Plant systematics. Elsevier Academic Press.
15. Quicke, D.L.J. 1993. Principles and Techniques of Contemporary Taxonomy. Blackie Academic and Professional (An imprint of Chapman & Hall.).

16. Radford, A.E., W.C. Dickinson, J.R. Massey and C.R. Bell. 1974. Vascular Plant Systematics, Harper and Row, New York.
17. Salemi, M. and A.-M. Vandamme (Eds.) 2003.The Phylogenetic Handbook. A Practical Approach to DNA and Protein Phylogeny. Cambridge University Press.
18. Sivarajan, V.V. 1991 (2nd ed.). Introduction to the Principles of Plant Taxonomy (Ed. N S K Robson). Oxford and IBH publishing Co. Pvt. Ltd.
19. Stuessy, Tod F., 2009. Plant taxonomy : the systematic evaluation of comparative data (2nd ed.). New York : Columbia University Press.

BTY 5311	**ECONOMIC BOTANY** (Credits 4; Theory 3 hrs; Practical 3 hrs)
Aim	The aim of Plants and Society course is to expose students to society's historical and ongoing connection to plants.
Objective(s)	• To understand the global issues such as population increase, climate change and food security. • To understand the economic value of plants and their importance in the sustenance in human way of living.. • Understand the past relationship between the plants and people and the future role of the plants for society.
Learning outcome	After the completion of this course, students will be able to: • To appreciate how plants influenced our past and how they will influence our future. • Exploreplants for economic values like food, medicine and energy resources. • Understand the economic and commercial values of plants for human health.
S. No.	**Theory**
1.	Plants and society: Introduction to the connections between plants and people in the past and the future influence of plants on society.
2.	**Origin of agriculture:** when, where and why? Centers of origin of major crop plants, their domestication, evidences in favor of domestication and spread of crop plants across continents.
3.	**Origin of crop plants:** concepts and theories of evolution of crop plants, evolution due to domestication: documenting time and event of domestication, changes due to domestication at gene and genome level, modern breakthrough discoveries in genetics and fast forward domestication.
4.	**Feeding the world:** Modern agriculture and global food security issues-the green revolution and beyond, food security dimensions-challenges and solutions, challenges to food production and land expansion, competition between bioenergy crops and food cops for land, increasing photosynthetic efficiency of the crop plants. Climate change, plants and food security: Climate smart agriculture (CSA), breeding for crop improvement, alternative crops for future, sustainable development goals (SDG's) and beyond.
5.	**Plants for food:** Essential components of human nutrition: Cereal & pseudo-cereal crops, legume crops, pulses, oil seed crops, root crops, sugar and starch crops. **Plants as Vegetables:** Vegetable crops and vegetable oil crops, problems associated with the storage and transportation of vegetable crops, vegetable availability maps of India. **Fruits & Nuts:** Nutritional value, preservation and storage; challenges to storage and transportation of fruits, Economics of losses incurred due to inadequate storage and transportation facilities. Fruits availability maps

	of India. Institutes/Organizations involved in fruit crops in India and world.
6.	Stimulating beverages, psychoactive plants, poisonous and allergy plants, biofuel crops.
7.	**Herbs and Spices:** essential oil plants, chemistry and extraction of essential oils, scents and perfumes. History of spices, ancient trade, diffusion of spices across the continents. General account on Herbs; Consumption and production, global distribution and pattern of culinary herbs.
8.	**Other plant products:** Timber, fibres, associated materials (turpentine, gums, resins, waxes, industrial chemicals), rubber, dyes, cloth, wood and paper, NWFPs (Non wood Forest Products).
9.	**Plants and Human Health:** History of important medicinal plants, global Distribution, Plant secondary metabolites, Methods for analysis of plant metabolites, Threats to the medicinal plants and conservation strategies. Bioprospecting of medicinal plants, metabolomics and other omics approaches for medicinal plants and human health, Genetic engineering of important medicinal bioactive compounds, challenges to production of bioactive compounds, role of new genetic technologies for medicinal plants.
S. No.	**Laboratory/ Practical/Field work/ Community Interaction**
1.	Study plants for various nutritional purposes.
2.	Collection of seeds from the local communities.
3.	Study of medicinal plants for screening of bioactive metabolites.
4.	Documenting the various threats to the medicinal plants and the conservation of these plants.

Text Books:

1. Kochhar SL. 1981. Economic botany in the tropics. Laxmi Publications.
2. Kochhar SL. 2016. Economic Botany: A Comprehensive Study. Cambridge University Press.
3. Levitin E &MacMohan K. 2011. Plants & Society. The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY.
4. Wickens GE. 2001. Economic Botany: Principles and Practices. Kluwer Academic Publishers.
5. FAO. How to Feed the World in 2050? http://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf.
6. WRI. How to Sustainably Feed 10 Billion People by 2050, in 21 Charts. https://www.wri.org/blog/2018/12/how-sustainably-feed-10-billion-people-2050-21-charts.
7. Wise TA. 2013. Can We Feed the World in 2050? A Scoping Paper to Assess the Evidence. GLOBAL DEVELOPMENT AND ENVIRONMENT INSTITUTE WORKING PAPER NO. 13-04.
8. Latest research articles/review articles will be provided to the students by the concerned faculty.

BTY 5312	**PLANT-PATHOGEN INTERACTIONS** (Credits 4; Theory 3 hrs; Practical 3 hrs)
Aim	To educate post graduate students about the different pathogen groups and how they interact with plants
Objectives	• To learn about major pathogen groups that infect plants • The impact of the plant diseases on food security and ecosystems

	• 3. To learn about the ways in which plant defend against the pathogens and how to manipulate plant -pathogen interaction in favor of plants
Learning outcome	After completion of this course ➢ The students can identify different pathogens and their symptoms in different crop plants. ➢ Understand the molecular mechanism of plant pathogen interactions. ➢ Will know the different methods to diagnose the plant diseases.
S. No.	**Theory**
1.	**Introduction:** why study plant diseases, important plant diseases that shaped the history of human civilization. 10 most important plant diseases of the world & India
2.	**Plant- Virus-Vector Interactions:** Plant viral diseases, symptoms, major viral pathogens. Viral genomes, size and nature of proteins, viral replication within the host cell and viral movement from cell to cell within the host. Viral movement from plant to plant.Insect vectors involved in transmission, persistent and non-persistent transmission. Plant response to viral pathogens and resistance mechanisms.
3.	**Plant- Bacterial Interactions:** Plant bacterial diseases, classes of plant pathogenic bacterium, general symptoms. Alpha and beta Proteobacterialphytopathogens (Agrobacterium and Ralstonia), gamma Proteobacterialphytopathogens (Erwinia, Xanthomonas). Gram-positive and fastidious phytopathogenic bacteria: Clavibacter and Xylella. Quorum sensing, Virulence factors- Toxins, EPS, Cell wall degrading enzymes, type I, II, III and IV secretion system. Regulation of Hrp genes, harpins and type III effectors. Modes of transmission. Plant response to pathogenic bacteria
4.	**Plant –Fungal interactions:** Necrotrophicphytopathogenic fungi – Diseases, symptoms, mode of pathogenesis, Host selective toxins, non-host selective toxins, Genetics of toxin biosynthesis and Toxin resistance, Plant susceptibility to toxins. Biotrophicphytopathogenic fungi – Diseases, symptoms, mode of pathogenesis, Specialized structures for nutrition, Effectors- apoplastic and cytoplasmic, Plant response to fungal infection and resistance, Quelling.
5.	**Plant – Nematode interactions:** Classes of plant parasitic nematodes, feeding organs, Ecto and Endo parasitic nematodes, Nematode dissemination, important plant diseases caused by nematodes, Nematode effectors and host targets, Plant response to nematodes and resistance mechanisms.
6.	Plant interaction with parasitic plants.
7.	**Plant Resistance and Susceptibility factors:** Preformed defense**,** Host resistance and non-host resistance**,** Induced resistance and Systemic Acquired Resistance**,** PAMPS and PAMP Triggered Immunity (PTI)**,** Effector Triggered Immunity (ETI)**,** Effector Triggered Susceptibility (ETS)**.** Theories and models on Plant Resistance to pathogens
8.	**Applied Plant Pathology:** Methods of Plant pathogen diagnostics**.** Evolution of Plant Pathogen interactions- its significance on breeding disease resistant plants,Genetic engineering of Plants for resistance.
Sl.No	**Laboratory/Practical**
1	Plant disease symptoms: recognition and identification
2	Isolation of plant pathogen from diseased plant tissue
3	Application of Koch's postulate
4	Molecular diagnostics of plant pathogen using PCR
5	Detection of plant virus using ELISA

Text Books:

1. Agrios, G. N. 2006. Plant Pathology, Academic Press.
2. Dickinson,M. Molecular Plant Pathology. 2003. BIOS Scientific Publishers.
3. J.S. Huang. 2001. Plant pathogenesis and resistance: biochemistry and physiology of plant-microbe interactions. Kluwer Academic.
4. Roland N. Perry and Maurice Moens. Plant Nematology;, Published by CABI
5. Clarence I. Kado Plant Bacteriology, Published by American Psychopathological Society.
6. H.H. Prell and P. Day, Plant–Fungal Pathogen Interaction: A classical and Molecular View; Published by Springer-Verlag.

BTY 5313	**METHODS IN PLANT BIOLOGY** (Credits 4; Theory 4 hrs; Practical 3 hrs)
AIM	This course aims to make the learners understand the important methods and innovative research used in plant biology and rules in scientific writing. This will help the master students in carrying out their dissertation work and preparing their thesis.
Objectives	• To study the important methods applied in different research areas and their technological advances. • To expose graduate students to scientific writing and make them understand how the research findings can be documented and communicated in a scientific way.
Learning outcome	On the completion , the students will be able, ➢ To apply different methods for identifying the microbes, plants and their molecules ➢ To understand the statistical tools foranalyzing the experimental data. ➢ To understand the research topic, research problem, review of literature, conducting experiments, analyzing the data, reaching valid conclusions and communicating the outcome to scientific Journals.
	Theory
1.	**Microscopy**: Sectioning-Microtomy, Light microscope- Bright-field microscope, Dark-field, Phase-contrast, Differential interference contrast, Fluorescence, Laser dissection microscope, confocal microscopy Stereomicroscope, Transmission and scanning electron microscopy.
2	**Spectroscopy,** Principles and application: Beer and Lambert law, Colorimetry and spectrophotometry, Flame photometry and Atomic absorption spectrophotometry; Infrared spectroscopy- FTIR, NIR; Raman Spectroscopy; Nuclear Magnetic Resonance (NMR). Mass spectrometry**:** Basic principle and application; ESI-MS; MALDI-TOF; LC-MS; GC-MS; MS-MS
3	**Chromatography**, Principles and application: Paper chromatography, Thin layer chromatography (TLC); Column chromatography: gel filtration, adsorption, partition, affinity, ion exchange; HPLC; HPTLC; Gas chromatography.
4	**Anatomical and general plant biotechnological methods:** Stain and staining procedures, double staining, localization of pectin, suberin, phenols etc.; Regeneration protocols employing direct and indirect organogenesis/somatic embryogenesis; Centrifugation-Principles and application: types of centrifuges; Tracer techniques; Bioreactors, Fermenter.
5	**Flow cytometry Methods:** Principles of flow Cytometry, Nuclear DNA content measurement, Flow Cytometry and Ploidy: Applications in Plant Systematics, Ecology and Evolutionary Biology, Genome Size estimation, Analysis of endopolyploi**dy.**

6	**Structural biology and protein interactions:** Cryo electron microscopy, X-ray crystallography, Protein NMR, and X ray scattering;yeast two hybrid assay, split protein assays,co-immunoprecipitation and affinity purification. Protein Localization: Reporter genes, florescent protein tagging, immunostaining.
7	**Biostatistics:** Hypothesis testing (t-test, Chi-square test), Analysis of variance (ANOVA) - One way and two way, correlation, regression. Introduction to various statistical softwares.
8	**Scientific writing:** Review of literature; Content writing; preparing journal manuscripts; reference citing and copy right issues; impact factor and citation index.

S.No	**Laboratory/ Practicals**
1	Preparation of samples for microtome sectioning
2	Preparation of samples for microtome sectioning
3	Chromatographic separation of biomolecules (Proteins, oligosaccharides, neutral sugars etc.)
4	Chromatographic separation of biomolecules (Proteins, oligosaccharides, neutral sugars etc.)
5	Localization of lignin/Phenols
6	Quantitative estimation of protein using spectrophotometer
7	HPTLC: Separation of plant metabolites/pigments
8	HPTLC: Separation of plant metabolites/pigments
9	Auto fluorescence detection of plant phenolics
10	Review writing on selected topic

Text Books:

1. Steven E Ruzin. 1999. Plant microtechnique and microscopy: Oxford University Press
2. Walter F. 1980. The Microtome Manual of the Technique of Preparation and of Section Cutting. Germany; Ernst LeitzWetzlar GMBH
3. Banwell C N, McGraw-Hill: 1966, Fundamentals of molecular spectroscopy:Vol 1,Science
4. Snyder LR, Kirkland JJ, Dolan JW. 2009. Introduction to Modern Liquid Chromatography:Third Edition
5. Kirakosyan A,. Kaufman PB. 2009 Recent Advances in Plant Biotechnology:Springer, Boston, MA
6. Chawla HS. 2009, Introduction to Plant bio technology, third edition, Science Publishers
7. Harris RK, Roderick E. Wasylishen , Duer MJ. 2009 NMR Crystallography, Wiley,,first edition,
8. Daniel M. Bollag, Michael D. Rozycki and Stuart J. Edelstein, Protein Methods by 2 ed. Wiley Publishers
9. Bailey NTJ. 1969. Statistical Methods in Biology Published by The English Universities press L
10. Dolezel J, Greilhuber J and Suda J. 2005. Flow Cytometry with Plant Cells: Analysis of Genes, Chromosomes and Genomes. Wiley-VCH Publishers
11. Latest research articles/review articles relevant to the respective topics will be provided to the students by the concerned faculty

List of courses in Semester IV

Semester	**Course code**	**Course Title**	**Credit**
IV	BTY 5490	***DISSERTATION**	8

BPS 5490	***DISSERTATION**
S. No.	**Topic**
1.	***Dissertation:** The students have to carry out a Project/Dissertation of 8 credits and submit the thesis to the Department for internal and external valuation.The students are required to start their dissertation at the beginning of the 3rd Semester and they have to submit the dissertation at the end of the 4th semester.
2.	**Seminar Presentation/Open Defense:** The students will present the work done as a part of their Dissertation for valuation.
3.	**Objectives:** • **To train the students on how to undertake research in the feild of study** • **To educate students on how to approach a research problem, plan and execute experiments, analyze data and how to infer the outcome.**
4.	**Learning Outcome** ➢ **Have necessary skills to formulate a research question, frame hypothesis, make informed judgements on the choice of appropriate mehods or techniques to be used in the study** ➢ **Competent to plan and execute the experiment and collect the data scientifically.** ➢ **Competent to draw scientific conclusions and clearly articulate or communicate the outcome to the scientific community as well as general public.**

ELECTIVES COURSES

BTY 5001	**PLANT TISSUE CULTURE TECHNIQUES** (Credit 4; Theory 3 hrs; Practical 3 hrs)
AIM	To familiarize with plant tissue culture techniques
Objectives	• To teach different components used in tissue culture media and their specific uses. • To teach different methods of micro propagation and their advantages • To teach different techniques used in invitro conservation.
Learning outcome	After completion of the course, the students ➢ Are able to understand the principles of plant tissue culture and various *in vitro* techniques ➢ Proficient for developing haploid and triploid plants through tissue culture protocol. ➢ Understand the techniques of protoplast isolation, culture and fusion and their application in crop improvements.
Sl.No	**Theory**
1.	History of plant tissue culture, cellular totipotency: concepts and applications.
2.	Techniques of plant tissue culture, essential requirements of a plant tissue culture laboratory, Plant tissue culture media, General composition of the solid and liquid media, various gelling agents, media selection.
3.	Sterilization of medium, galsswares, instruments, plant material, transfer area, Preparation of explants, sterilization culture and incubation. Subculture and hardening. Micropropagation: various stages of micropropagation, importance.

4.	Principles and protocol applications of culture of different explants, embryo culture, importance of embryo culture
5.	Haploid plant production, Importance of haploid plants. Androgenesis: pre-treatment of anther/pollen grains, callus induction and shoot regeneration, androgenic embryos, their development. Merits and demerits of anther culture. Microspore culture, Protocol, Advantages of microspore culture over anther culture.
6.	*In vitro*gynogenesis, Ovary/ovule/flower bud culture, embryo induction from cultured ovary/ovule/flower bud, Callus induction from embryo sac cells and their organogenesis, advantages of gynogenenic plants over angrogenic plants
7.	Triploid plant production: Importance of triploid plants, endosperm culture, stage of endosperm culture, role of embryo in endosperm culture, advantages and limitations of triploid plants.
8.	Suspension culture, batch culture, continuous culture, single cell culture.
9.	Somatic embryogenesis: Factors affecting somatic embryogenesis, differences between somatic and zygotic embryogenesis, synthetic seed production, desiccated and hydrated synthetic seeds, merits and demerits of synthetic seeds, somaclonal variation and applications of somacloanl variation in crop improvement.
10.	Protoplast isolation, culture, plant regeneration from protoplast, protoplast fusion and somatic hybridization, cybrids.
11.	In vitro germplasm storage, in-situ conservation, ex-situ conservation, cryopreservation.
12.	Application of tissue culture for crop improvement, problems, limitations and future prospectus.
S. No.	**Practical**
1.	Preparation of the stock solutions of MS medium,
2.	Preparation of MS medium from stock solutions,
3.	Isolation, preparation, sterilization and inoculation of different explants like shoot tip, node, anther, embryo and cambium
4.	Isolation and fusion of plant protoplasts,
5.	Preparation of synthetic seeds,
6.	Preparation of selective medium for drought or salinity resistance. Preparation of MS soild medium from stock solutions containing auxin and cytokinin, NaCl or PEG, and inoculation,
7.	Find out the uninucleate stage of anther and anther culture
8.	Dissect out an embryo from any seed and culture it on a suitable solid medium.

Text Books:

1. Barbara M. Reed (2008) Plant Cryopreservation: A Practical Guide. Springer, Heidelberg.
2. Bhojwani SS, Razdan MK (1996) Plant tissue culture: Theory and Practice. Elsevier, North Holland
3. Colin Ratledge, Bjorn Kristianson (2001) Basic biotechnology. Cambridge University press.
4. Dixon RA, Gonzales RA. (2004) Plant cell culture, a practical approach (II Edn). Oxford University Press.
5. Erica E. Benson (1999) Plant Conservation Biotechnology. Taylor and Francis, USA
6. Evans DE, Coleman JOD, Kearns A (2003) Plant Cell Culture. Taylor and Francis, USA.

7. Gamborg L, Philips GC (Eds.) (2005) Plant cell, tissue and organ culture: Fundamental methods. Narosa Publishing House, New Delhi.
8. Hamish A Collin, Sue Edwards (1998) Plant tissue culture. Bios scientific publishers, India
9. Michael R. Davey, Paul Anthony (2010) Plant Cell Culture: Essential Methods. Wiley-Blackwell Publishers, India
10. Susan R. Barnum (1998) Biotechnology an introduction. Wadsworth Publishing Company, USA.
11. Wang TL, Cuming A. (1996) Embryogenesis the generation of a plant. Bios Scientific Publishers Limited, UK
12. William J Thieman, Michael A Palladino (2009) Introduction to biotechnology (II Edn). Pearson.

BTY 5002	**ALGAL BIOPROSPECTING** (Credit 3; Theory 2 hrs; Practical 3 hrs)
Aim	To study the commercial uses of algae by application perspectives
Objectives	• Methods of isolation and characterization of algae • Methods and techniques for algae cultivation • Techniques involved to extract and bioactive compounds from algae for commercial purpose..
Learning outcome	The learners get skill and knowledge to ➢ undertake large scale production of natural compounds, food supplements and pharmaceuticals from algae. ➢ Know about commercial value of algal compounds.
S. No	**Theory**
1.	Brief taxonomic descriptions and identification of micro and macro algae of fresh water and marine habitats. General principles of Culturing Algae in Laboratory and growth measurement. Isolation and Culture of Algae of different forms (single cell, colonial, filamentous and thallus forms). Chemical composition of Culture media for fresh water and marine algae (*Botryococcus, Chlorella, Dunaliella, Gracilaria, Kappaphycus, Sargassum*).
2.	Algal farming: Photobioreactor, Open pond and Raceway ponds. Various types of seaweed cultivation.
3.	Generalized uses of seaweeds,Human food, Seaweed Baths, Cosmetics, Seaweed as agricultural fertilizers, Liquid Seaweed Extracts, Seaweed industrial gums: Alginates, Agars, Carrageenans, other polysaccharides and their Medicinal Uses.
4.	Microalgae for high-value chemicals from algae: β-carotene, astaxanthin, docosahexaenoic acid, eicosahexaenoic acid, phycobilin pigments and algal extracts for cosmetics. Microalgae for cosmaceuticals, nutraceuticals and functional foods.
5.	Microalgae in liquid waste managements, Biological waste treatment, Algae-bacteriainteraction.
S.No	**Laboratory/Practical/Field collection**
1	Isolation and Culturing of fresh water and marine Algal forms in
2	Growth and growth measurement of algae using suitable medium.
3	Cultivation of microalgae using photobioreactor and in pilot pond
4	Recording rate of photosynthesis and respiration by Oxygraph

5	Algal biomass harvesting: Algae oil extraction by mechanical and chemical methods (Solvents/soxlet extraction).
6	Energy conversion: Pretreatment- Saccharification (Thermochemical processes).
7	Ethanol fermentation.

Text Books

1. Stein,H. 1973. Handbook of Phycological methods. Culture methods and growth measurements, Cambridge University Press.
2. Laban,S.C. and Wynne, M.J. 1981. The Biology of seaweeds, University of California Press.
3. Sieg, D. 2011. Making algae biodiesel at Home.
4. Gavin C. Torn, Jr. (1988) Manual on seaweed culture – FAO Manual.
5. Klaus Lüning (1990) Seaweeds: their environment, biogeography and ecophysiology, Wiley-IEEE
6. Clinton J. Dawes (1998) Marine Botany, 2nd ed, John Wiley & Sons, Inc.
7. Relevant information in the reviews and research articles.

BTY 5005	**GENOME STABILITY AND DNA REPAIR** (Credits 2 ; Theory 2 hrs)
Aim	To understand the basis of genomic stability, mutations, their cause, repair and methods of screening
Objectives	• To study the types of mutations and their causes • To study how DNA mutations are repaired • To study different methods used to screen mutations •
Learning outcome	Students after completion of this course will know ➢ Different types of mutations, mutagens and their mechanisms of DNA damage and repair ➢ methods to screen mutants.
	Theory
1.	**Mutagens and mutations:** Biochemical basis of mutations and mutagens Types of mutations – ploidy changes, chromosomal aberrations such as additions, deletions, translocations, duplications, inversions, molecular mutations such as point mutations and frame-shift mutations, recombinations (at chromosome and DNA level), trinucleotide-repeat expansion, mutational hot spots
2.	**Transposons and retrotransposons as mutagens**: Historical background of transposons Structure of typical transposons and types of transposons and retrotransposons Genetic and evolutionary significance, implications in genome plasticity
3.	**DNA repair:** Types of DNA repair in prokaryotes and eukaryotes DNA recombination models
4.	**Screening of mutations:** Techniques to screen chromosomal mutations, based on microscopy, flow cytometry and hybridisation Techniques to screen molecular mutations, in prokaryotes and eukaryotes, based on PCR, real time PCR, electrophoresis, arrays, sequencing, Ames test, eukaryotic detector mutants Absolute and relative quantification of mutations Advantages and disadvantageous of the techniques

Text Books:

1. Watson JD, Tania AB, Stephen PB, Alexander G, Michael L, Losick Richard L. 2017. Molecular Biology of the Gene, 7th edition. Pearson Education.
2. Krebs JE, Goldstein ES, Kilpatrick ST. 2017. Lewin's GENES XII. Jones and Bartlett Publishers,Inc.
3. Lodish H, Berk A, Kaiser CA, Krieger M, Bretscher A. 2016. Molecular Cell Biology, 8th edition. W H Freeman & Co.
4. Alberts B. 2014. Molecular Biology of the Cell, 6th edition. Garland Science.
5. Daniel L. Hartl DL, Cochrane B. 2017. Genetics: Analysis of Genes and Genomes 9th edition. Jones & Bartlett Learning.
6. Griffiths AJF, Wessler SR, Carroll SB, Doebley J. 2015. Introduction to Genetic Analysis, 11th edition. W.H. Freeman & Worth Publishers.
7. Stryer L, Berg JM, Tymoczko JL, GattoJr GJ. 2019. Biochemistry, 9th edition. W. H. Freeman.
8. Sharma AK, Sharma A. 1980. Chromosome Techniques - Theory and Practice, 3rd edition. Elsevier.
9. Meksem K, Kahl G. 2010. The Handbook of Plant Mutation Screening: Mining of Natural and Induced Alleles. Wiley.
10. Cotton RGH, Edkins E, Forrest S (Eds.). 1998. Mutation Detection: A Practical Approach (Practical Approach Series), 1st edition. IRL Press.

BTY 5003	**RECENT ADVANCES IN PLANT BIOLOGY** (Credits 3; Theory 3 hrs)
Aim	To educate post graduate students on grand challenges and important questions in Plant Science
Objectives	1. To educate and stimulate discussions on trending topics in Plant Science 2. To encourage students to think and read beyond the limits of the program
Learning outcome	On completion, the students are able to ➢ Understand the needs and methods of organic farming and nutraceuticals and their health benefits. ➢ Methods to explore the plant cells or systems for nanobiotechnological applications. ➢ Understand climate change effect on crop plants.
S. No	**Theory**
1.	Organic farming: methods and approaches, sustainable intensification of farming, why farm organically.
2.	Nutraceuticals: classification, health benefits, nutritional therapy, global demand, regulations.
3.	Nano-biotechnology: definition and concepts and applications; Cellular Nanostructures; Nanopores; Biomolecular motors; Criteria for suitability of nanostructures for biological applications, Colloidal nanostructures; Nanovesicles; Nanospheres; Nanocapsules Nano biosensors, Nano pesticides and nano herbicides, Nano bio farming, use of carbon nano tubes in biotechnology, nano additives in food, Nanoparticles for diagnostics and imaging.
4.	Global climate change: carbon pollution and human activities that promote global warming, Impacts on global flora, impact of climate change on pollination, predictions, Plant responses to climate change. Approaches to adapt and mitigate climate change, ensuring food security and protecting bio diversity, restoration of ecosystems and re-engineering. case studies and discussion of recent research articles
5.	Precision genome engineering: sequence specific nucleases, ZFN, TALEN, CRISPR/cas9 and their use in chromatin modification and

	epigenetic regulation, transcriptional repression, transcriptional activation, gene editing and genome editing.

Text Books:

1. David S.Goodsell 2004. Bionanotechnology: Lessons from Nature. Wiley Publishers.
2. Aluko, R. 2012. Functional foods and nutraceuticals: springer.
3. Latest research articles/review articles relevant to the topics

BTY 5004	**ETHNOBOTANY: PLANTS, PEOPLE AND CULTURE** (Credits 2;Theroy 2hrs)
Aim	The aim of the course is to introduce students to the science of how people use plants in different cultures and societies (ethnobotany), with emphasis on current research and issues.
Objective(s)	The objectives of this course are to: • Introduce students with the basic concepts of ethnobotany with emphasis plant-human interactions. • Make students familiar with scientific methods of plant collection, including identification and curation and ethnobotanical methods of collecting plant-use information from indigenous people and how this information contributes to our understanding of the usage of plants for various purposes.
Learning outcome	After the completion of this course, students will be able to: ➢ Understand the importance of ethanobotany and use of traditional knowledge in India. ➢ Know about the ethnobotanical survey techniques. ➢ Understand the ethnobotanical knowledge and analyze the data for research and drug discovery.
S. No.	**Theory**
1.	Introduction to Ethnobotany, Traditional Knowledge (TK), Traditional Knowledge Resource Classification (TKRC), importance of traditional knowledge, Traditional plant knowledge of Indian tribes - sources and problems, Traditional Knowledge Digital Library (TKDL).
2.	Usage of indigenous plants in different cultures of the world for various purposes, Interactions of humans and plants in the past in cultures around the world: archaeobotany, paleoethnobotany, ethnohistory. Evidences in favour of biodiversity and sustainability as ethnobotanical principles of human interactions with plants.
3.	Plants used for food, medicine, materials and spiritual purposes in different cultures of the world.
4.	Global movement of plants and human cultures, importance of ethnobotany in traditional and modern culture, Cultural relevance of the native flora to the indigenous cultures of the World. Importance of ethnobotanical knowledge in community decision-making processes
5.	Ethical issues and bioprospecting, Biopiracy, World Trade Organisation (WTO) and TK, provisions of Conventions on Biological Diversity (CBD) related to traditional knowledge.
6.	Ethnobotany and Plant Conservation, Ethnobotany and Germplasm diversity.
7.	Methods in ethnobotanical research: Quantitative Ethnobotany and survey field methods, methods of collecting plant-use information from indigenous cultures, and ways that this information contributes to other

	fields of study, such as resource management, community development, and human health, applications of multivariate and statistical methods (Cluster and Principal Component Analysis, ANOVA, Regression Analysis, Correlation etc.) in Ethnobotany.Ethics in ethnobotany research.

Text Books:

1. Levitin E and MacMohan K. 2011. Plants and Society. The McGraw-Hill Companies, Inc., 1221, Avenue of the Americas, New York, NY.
2. Cunningham, A B. 2001. Applied Ethnobotany: People, Wild Plant Use and Conservation. Earthscan Publications Ltd. London and Sterling, VA.
3. Gary J Martin 1995. Ethnobotany: A Methods Manual by. Springer-Science+Media, B.V.
4. Balick, M. and P A. Cox. 1996. Plants, People, and Culture: The Science of Ethnobotany. Scientific American Library, A division of HPHLP, New York.
5. Cotton, C M. 1997. Ethnobotany – Principles and Applications. John Wiley and Sons Limited. New York, USA.
6. Jain, SK. 1989. Methods and Approaches in Ethnobotany. Society of Ethnobotanists. Lucknow.
7. Schultes, RE., & Reis Sv. 1995. Ethnobotany. Evolution of a discipline. Chapman & Hall. London
8. Latest research articles/review articles will be provided to the students by the concerned faculty.

BTY 5006	**BIOMASS AND BIOENERGY**(Credits 3; Theory 3hrs)
AIM	This course aims to make the learners understand how plant biomass can be utilized to generate bioenergy
Objectives	• To understand the current International and national status of biofuel production • To know the structure of cell wall polymers and their conversion to biofuel by efficient pretreatment methods • To discuss the major bottlenecks in the biofuel productions from plants
Learning outcome	After completion of the course, students will, ➢ Understand the potential of biomass for sustainable energy production. ➢ Understand the different biomass constituents for sustainable production of value added compounds. ➢ Know about the plant biomass conversion into various energy production.
S.No	**Theory**
1	Fundamental concepts in understanding biofuel/bioenergy production- Various biofuels/bioenergy from biomass
2.	Bioenergy current status: National and international; Biofuel generations (first, second, third and fourth), Recent advances in second generation biofuel production and its advantages, Feedstocks. - Important bioenergy crops, agri-residues, oil seeds.
3	Plant cell walls: Renewable energy resource of biofuel; Derivation of cell walls and wall architecture- Cellulose, Hemicelluloses, Pectic polysaccharides, Hydroxycinnamates, mixed linked glucans, proteins and glycoproteins, Lignin, Value added products from lignin, suberin, cutin, waxes; Recalcitrance of cell wall

3	Cell wall profiling: Compositional analysis of cell wall using different biochemical and analytic methods such as HPLC, GC, FTIR etc.
4.	Biosynthesis of cell wall polymers-General mechanism of polymer assembly. Glycosyltransferases and polysaccharide synthases, regulation of polysaccharide synthesis; Wall polymers: Extraction and fractionation
5	Cell wall degradation- Biomass pretreatment; different pretreatment methods-Physical, Chemical, Biological, Recent advances in cost effective pretreatment methods; Microbial source for cell wall degrading enzymes: Cellulolytic, Xylanolytic and Ligninolytic microbes and their identification.
6	Saccharification and fermentation: Estimation of the saccharificationefficiency of the pretreated biomass; Factors affecting saccharification, Simultaneous saccharification and Fermentation.
7	Modification/ engineering of plant cell wall for better fuel production: Hemicellulose and Lignin engineering
8	Environmental and economic aspects: Environmental impacts of biofuel production; Value-added processing of biofuel residues and co-product
9	Policies and regulations on biofuel production; biofuel polices, underlying drivers, technical standardisation

Text Books:

1. Goldstein WE. 2016. The Science of Ethanol:CRC Press;
2. Fry SC. 2001. The Growing Plant Cell Wall: Chemical and Metabolic Analysis The Blackburn Press
3. Hayashi T. 2006. The Science and Lore of the Plant Cell Wall: Biosynthesis, Structure and Function Brown Walker Press
4. Linskens HF and Jackson, JF. 2011. Plant Cell Wall Analysis. Springer; Softcover reprint of the original 1st ed. 1996 edition
5. Ahluwalia VK 2018. Renewable Energy In india; Impacts and Responses for the Built Environment. Booh Shores, ,second edition
6. Singh RS and Pandey A. 2017. Biofuels Production and future Prospectives. Edgardgnansounou, crc press
7. Shoukat S. 2011. Progress In Biomass and Bioenergy Production:vol 7,IntechOpen
8. Khanna M and Zilberman D. 2017. Handbook of Bioenergy Economics and Policy: Springer
9. Marco Aurelio Dos Santos Bernardes. 2011. Biofuel production:;Recent Developments and Prospects:vol 8,IntechOpen
10. Lima MAP, PolicastroNatalense AP. 2012. Bioethanol:Intech,
11. Albersheim P, Darvill A, Roberts K, Sederoff R and Staehelin A. 2010. Plant Cell Walls. Garland Science; 1 edition
12. Li Y and S.K. Khanal SK. 2016. Bioenergy: Principles and Applications. ISBN 9781118568316 (paper) / 9781118568378 (epub). Wiley Blackwell
13. Vairavan K, Thukkaiyannan P, Paramathma M Venkatachalam P, Sampathrajan A. 2007. Biofuel Crops: Cultivation and Management (Jatropha, Sweet Sorghum and Sugarbeet) Published by Agrobios

BTY 5007:Hands on training on Plant metabolites and Drug discovery
(Credits 3; Theory 2 ;Practical 3 hrs)

Objectives	This course is designed to teach, • tissue culture techniques for mass culturing of plant cells for extraction • , extraction, separation, identification and bio-evaluation of phytochemicals.
Learning outcomes	Upon successful completion of this course, students are ➢ Able to know how to cultivate the microbes and plants cells ➢ have the knowledge on the extraction, isolation, purification and characterization of bioactive compounds of commercial importance. ➢ will have the competence to initiate start-ups or job opportunity in phytochemical and pharmaceutical industries.
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1.	**Plant resources:** Plant cell cultures including bacteria, fungi, algae, callus production.
2.	**Methods of Extraction:** Solvent Extraction methods-Maceration,Decoction, Reflux extraction, Soxhlet extraction, ultrasonic and microwave-assisted extraction. **Methods of Separation, Isolation and concentration:** Separation by solvent method-polarity gradient separation; precipitation methods, salting out, dialysis**;** Separation byChromatography Ion-exchange, gel-filtration, HPLC and HPTLC; Concentration by evaporation- Lyophilization and flash evaporation.
3.	**Identification of phytochemicals by chromatographic techniques:** Phenolic Compounds, Terpenoids, Organic Acids, Lipids and Related Compounds, Nitrogen Compounds, Sugars and their Derivatives, Macromolecules like nucleic acids; Proteins; Polysaccharides by HPLC and HPTLC.
4.	**Biosynthesis and characterization of nanoparticles:** Silver nanoparticle synthesis using plant extracts like polysaccharides, Phenolic Compounds and Terpenoids.
5.	**Identification and characterization of phytochemicals by various analytical and spectroscopic methods:** UV/Visible, Fluorescent, FTIR and XRD and FE-SEM.
6.	**Bio-evaluation:** Anti-oxidants, Anti-viral, Anti-bacterial, anti-fungal and anti-cancer by cell line assay.
7.	**Practicals:** • Introducing basic protocols in cell culture-Bacteria, Fungi, Algae and Callus. • Analysis of monosaccharide components in poly/oligosaccharides by HPLC • Soxhlet extraction of plant metabolites • Extraction and partial purification of crude enzyme samples • Gel filtration chromatography for separation of oligosaccharides • Concentration of the plant/algal extracts by lyophilisation and flash evaporation. • Silver nanoparticle synthesis using plant/algal polysaccharides

	• Identification of phenolic compounds by HPTLC • Characterization of plant/algal polysaccharides by FTIR • Isolation and characterization of plant/algal polysaccharides using XRD • Analyzing antioxidant/anticancer/antiviral properties of plant/algal polysaccharides

Reference Manuals:

1. Arunkumar,K., Rathinam Raja, V. B. Sameer Kumar, Ashna Joseph, T. Shilpa and Isabel S. Carvalho. 2020. Antioxidant and cytotoxic activities of sulfated polysaccharides from five different edible seaweeds, *Journal of Food Measurement and Characterization*,51.
2. Hahn-Deinstrop E. Applied Thin Layer Chromatography:Best practice and avoidance of Mistakes. Wiley-VCH, Weinheim, Germany. 2000.
3. Hancock WS. High Performance Liquid Chromatography in Biotechnology. Wiley-Interscience, New Jersey, USA. 1990.
4. Harborne JB. Phytochemical Methods: A guide to modern techniques of plant analysis. 2nd Edition. Chapman and Hall publishers: 3, Springer. Germany.1998
5. Jim Clark (Chemguide.co.uk); Introducing Chromatography: Thin Layer Chromatography; Jun 6, 2019
6. Katz ED. High Performance Liquid Chromatography:Journal of Pharmacognosy and Phytochemistry Principle and Methods in Biotechnology (Separation science Series). John wiley& sons, New Jersey, USA.1995
7. Mark F. Vitha Spectroscopy: Principles and Instrumentation ISBN: 978-1-119-43664-5
8. Roseline, T.A., Murugan, M., Sudhakar, M.P., Arunkumar, K.2019. Nanopesticidal potential of silver nanocomposites synthesized from the aqueous extracts of red seaweeds, *Environmental Technology and Innovation*, 13 , pp. 82-93.

BTY 5008: Organic Farming - A Do It Yourself Course for Self-Reliance (Credits 0; Theory 1 hr Practical/Practice 4 hrs)	
Objectives:	It is an open elective course, intended to train students for self-sustainable organic farming. • To study the various concepts in organic farming • To get a hands-on-experience of farming, agro-processing, sales, marketing and agro-economics.
Learning outcome:	On completion of the course, the students will be armed with farming skills, the know-how of agro-processing, and entrepreneurship. Starting from kitchen garden, the course will arm the students with know-how to scale up farming to commercial level.
1	Introduction to organic farming: Concept and definition, its relevance to Indian and global agriculture, its future prospects.

2	Land use and organic manure: Land use, tillage, soil fertility, nutrient recycling, organic residues, organic manures, composting, soil biota and decomposition of organic residues, earthworms and vermicompost, weeding, diseases and insect pest management.
3	Cropping systems: Crop rotation, multiple and relay cropping system, intercropping.
4	Marketing and Sales: Agro-processing, sales and marketing
	Practices: Intercropping and organic cultivation: • Soil testing • Selection of appropriate crops for cultivation and raising the seedlings in germination trays • Land preparation in parallel • Planting • Manuring at appropriate intervals • Pest control using organic method, if required Preparation of organic manure: • Raising earthworms • Collecting appropriate organic waste • Preparation of vermicompost and other organic manure Hands-on training for agro-processing, sales and marketing • Agro-processing • Marketing, sale and account maintenance of farm products and organic manure

Reference:

1. S.P. Palaniappan, K. Annadurai (2018) Organic Farming: Theory and Practice. Scientific Publishers, India.
2. S.R. Reddy (2017) Principles of Organic Farming, Kalyani Publishers, India.
3. P L Maliwal (2020) Principles of Organic Farming. Scientific Publishers, India.
4. Gangopadhyay, A. (2007) Crop Production Systems and Management. Gene Tech Books, India.
5. Ananthakrishnan, T. N. (ed.) (1992) Emerging Trends in Biological Control of Phytophagous Insects. Oxford & IBH.
6. Francis, C. A. (1986) Multiple Cropping system. McGraw Hill Higher Education, New York.
7. Joshi M and Parbhakarasetty, T.K. (2005) Sustainability through Organic Farming. Kalyani Publishers, India.