

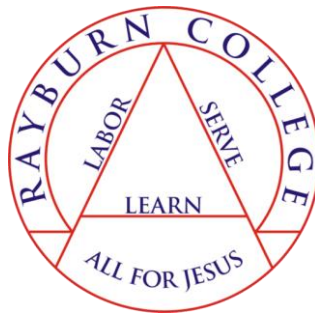
Choice Based Credit System (CBCS)

RAYBURN COLLEGE

(Autonomous, Accredited B++ Grade, 2.96 CGPA out of 4 by NAAC 2023)

Affiliated to M.U: No. MU/1-65/98/CDC/136:07.08.2012.

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DEPARTMENT OF BOTANY

UNDERGRADUATE PROGRAMME

(Courses effective from Academic Year 2024-25)

Semester – I

Core Course

Paper Code: BOTC-101

Paper Title: Viruses, Bacteria, Fungi and Plant Pathology (Theory)

Credit: 4

Unit I: Viruses

12 Lectures

History, nature, biochemical composition and structural organization (helical and icosahedral symmetry) of viruses; Classification (Baltimore); Nomenclature of plant viruses; Genome organization and replication of tobacco mosaic virus (TMV) and bacteriophage (T-phage); Lytic and lysogenic cycle, Symptoms and transmission of plant viral diseases; Structure, properties and importance of viroids and prions.

Unit II: Bacteria

15 Lectures

Overview of cell structure and function in the prokaryotes (Bacteria and Archaea); Classification of prokaryotes based on cell structure (Archaea, Gram-positive and Gram-negative bacteria, Mollicutes); Metabolic diversity of bacteria (phototrophy, chemolithotrophy, autotrophy, heterotrophy, fermentation); Bacterial cell division and microbial growth; Bacterial genome and plasmids; Reproduction and genetic recombination; Microbial growth control; Bacterial culture and staining; Economic importance of bacteria.

Unit III: Fungi

18 Lectures

General characteristics; Thallus organisation; Cell wall composition; Nutrition; Classification; Reproduction in fungi; Economic importance of fungi; Characteristics and life cycles of the following fungal species: Chytridiomycota – *Synchytrium*, *Allomyces*; Oomycota - *Phytophthora*, *Albugo*; Zygomycota – *Rhizopus*, *Mucor*; Ascomycota *Saccharomyces*, *Nerusporea*; Basidiomycota - *Puccinia*, *Agaricus*; Deuteromycota (mitosporic fungi) - *Fusarium*, *Aspergillus*.

Myxomycota - General characteristics; Status of slime molds; Occurrence; Classification.

Lichens: Classification; Thallus organization; Reproduction; Physiology and economic importance.

Mycorrhiza – Ectomycorrhiza and endomycorrhiza and their significance.

Unit IV: Plant Pathology

15 Lectures

History of plant pathology; Terms and concepts; Plant disease symptoms; Host- Pathogen relationships; Disease cycle and environmental relation; Methods of control of plant diseases; Plant quarantine; Fungal diseases – late blight of potato, brown leaf spot of rice, black rust of wheat; Bacterial diseases – citrus canker, angular leaf spot disease of cotton and bacterial blight of rice; Viral diseases – tobacco mosaic virus, vein clearing and tomato yellow leaf curl viruses.

Paper Code: BOTC-102(P)

Paper Title: Viruses, Bacteria, Fungi and Plant Pathology (Practical)

Credit: 2

1. Electron micrographs/Models of viruses – T4 and TMV, Line drawings/ Photographs of lytic and lysogenic cycle.
2. Collection and study of herbarium samples of virus plant diseases.
3. Types of bacteria from temporary/permanent slides/photographs. Electron micrographs or charts of bacterial binary fission, endospore, conjugation.
4. Gram-staining of root nodule bacterium (*Rhizobium*) and curd (*Lactobacillus*).
5. *Rhizopus* and *Mucor*: study of asexual stage from temporary mounts and sexual structures through permanent slides.
6. *Saccharomyces* and *Aspergillus*: study of asexual stage from temporary mounts and sexual structures through permanent slides.
7. *Alternaria* and *Fusarium*: Preparation of temporary mount.
8. *Puccinia*: preparation of temporary mount of different spores on wheat.
9. *Agaricus*: sectioning of gills.
10. Study of morphology and anatomy of lichens (crustose, foliose and fruticose) through temporary mounts/permanent slides.
11. Collection of herbarium specimens and study of pathological characteristics through temporary mounts/permanent slides of bacterial diseases (citrus canker, angular leaf spot of cotton); Viral diseases (TMV, vein clearing); Fungal diseases (early blight of potato/ white rust of crucifers, black stem rust of wheat and brown leaf spot of rice).

Suggested readings

1. Agrios, G.N. 1997. Plant Pathology, 4th edition, Academic Press, U.K.
2. Alexopoulos, C.J., Mims, C.W., Blackwell, M. 1996. Introductory Mycology. 4th edition. John Wiley & Sons (Asia) Singapore.
3. Pandey. B.P. 2014 Modern Practical Botany, (Vol-I) S. Chand and Company Pvt. Ltd., New Delhi.
4. Pelczar, M.J. 2001. Microbiology, 5th edition, Tata McGraw-Hill Co, New Delhi.
5. Sarbhoy, A.K. 2006. Text Book of Mycology, ICAR Publications, New Delhi.
6. Sethi, I.K. and Walia, S.K. 2011. Text book of Fungi and Their Allies, Macmillan Publishers India Ltd.
7. Sharma, P.D. 2011. Plant Pathology, Rastogi Publication, Meerut, India.
8. Sharma T.A., Dubey, R.C. and Maheshwari, D.K. 1999. A Text Book of Microbiology. S Chand and Co, New Delhi
9. Singh, R. P. 2007. Microbial Taxonomy and Culture Techniques, Kalyani Publication, New Delhi.
10. Webster, J. and Weber, R. 2007. Introduction to Fungi. 3rd edition. Cambridge University Press, Cambridge.
11. Wiley, J.M, Sherwood, L.M. and Woolverton, C.J. 2013. Prescott's Microbiology. 9th Edition. McGraw Hill International.

Core Course

Paper Code: BOTC-103

Paper Title: Algae, Bryophytes, Pteridophytes and Gymnosperms (Theory)

Credit: 4

Unit I: Algae

15 Lectures

Characteristic features, range of thallus organization, cell structure and components, pigment system, reserve food materials, reproduction and classification proposed by Fritsch and Lee. Thallus structures, reproduction and life cycle of Cyanophyta (*Nostoc*, *Oscillatoria*, *Spirulina*); Chlorophyta (*Chlamydomonas*, *Volvox*, *Oedogonium*, *Coleochaete*); Charophyta (*Chara*); Xanthophyta (*Vaucheria*); Phaeophyta (*Ectocarpus*); Rhodophyta (*Polysiphonia*) and the economic importance of Algae.

Unit II: Bryophyta

15 Lectures

Comparative and evolutionary trends in liverworts, hornworts and mosses. Progressive sterilization of the sporophytes, general characters, classification, structure of gametophytes and sporophytes, method of reproduction and life cycle of *Riccia*, *Marchantia*, *Pellia*, *Porella*, *Anthoceros*, *Sphagnum*, *Funaria*.

Unit III: Pteridophytes

12 Lectures

General characteristics and classification, early land plant (*Cooksonia* and *Rhynia*), reproduction and life cycle of *Psilotum*, *Lycopodium*, *Selaginella*, *Equisetum*, *Pteris*, *Marsilea*. Apogamy and Apospory, Heterospory and Seed habit, Telome theory, Stellar evolution, Ecological and economic importance.

Unit IV: Gymnosperms

18 Lectures

Characteristic features and classification of Gymnosperms, morphology, reproduction and life cycle and economic importance of *Cycas*, *Pinus*, *Gnetum*, *Ephedra* and *Ginkgo*.

Polyembryony and pollination drop with special reference to *Pinus*. Economic importance of Gymnosperms.

Palaeobotany: Geological time scale and dominant fossil flora of different ages, Fossil formation and types of fossilizations.

Paper Code: BOTC-104(P)

Paper Title: Algae, Bryophytes, Pteridophytes and Gymnosperm (Practical)

Credit: 2

1. Study of vegetative and reproductive structures of *Nostoc*, *Chlamydomonas*, *Volvox*, *Oedogonium*, *Chara*, *Vaucheria*, *Ectocarpus*, *Fucus* and *Polysiphonia* through temporary preparation and permanent slides.
2. Microscopic study of morphology and reproductive structure of *Riccia*, *Marchantia*, *Pellia*, *Porella*, *Anthoceros*, *Sphagnum*, *Funaria* through temporary and permanent slides.

3. Microscopic study of morphology and reproductive structure of *Psilotum*, *Lycopodium*, *Selaginella*, *Equisetum*, *Pteris* through temporary and permanent slides.
4. Study of morphology and microscopic reproductive structure of *Cycas*, *Pinus*, *Gnetum*, *Ephedra*, *Taxus* through temporary and permanent slides. Examination of available specimens/slides of fossil plants.

Suggested readings

1. Bhatnagar S.P., Moitra, A. 1996. Gymnosperms. New Age International Publishers, New Delhi, India
2. Kaur I., Uniyal P.L. 2020. Text Book of Bryophytes. New Delhi, Delhi: Daya Publishing House.
3. Kaur I., Uniyal P.L. 2019. Text Book of Gymnosperms. Daya Publishing House, New Delhi.
4. Kumar, H.D. 1999. Introductory Phycology, 2nd edition. New Delhi: Affiliated EastWest Press.
5. Lee, R.E. 2008. Phycology, 4th edition. Cambridge University Press.
6. Pandey S.N., Misra, S.P., Trivedi, P.S. 1983. A Textbook of Botany Vol. 2. Bryophyta, Pteridophyta, Gymnosperms and Palaeobotany. Vikas Publishing House Pvt. Ltd., New Delhi.
7. Parihar, N.S. 1972. An Introduction to Embryophyta. Vol.II: Pteridophyta. Allahabad, UP: Central Book Deport.
8. Parihar, N.S. 1991. An Introduction to Embryophyta. Vol. I: Bryophyta. Allahabad, UP: Central Book Deport.
9. Vashistha P.C., Sinha A.K., Kumar A. 2010. Pteridophyta. S. Chand. Delhi, India.

Skill Enhancement Course

Paper Code: BOTS-105

Paper Title: Biofertilizers (Theory)

Credit: 2

Unit I

8 Lectures

Introduction, types and importance of bio-fertilizers in agriculture, organic farming system and biocontrol of plant diseases; History of bio-fertilizers production; Micro-organisms used in bio-fertilizer production- *Rhizobium*, *Azobacter*, *Azospirillum*, Cyanobacteria, Mycorrhiza, Actinomycorrhiza.

Unit II

8 Lectures

Classification of biological nitrogen fixation; factors influencing nitrogen fixation; Rhizobia, process of nodule formation, role of Nif and Nod gene in biological nitrogen fixation; *Azolla* and *Anabaena* association, cyanobacteria in rice cultivation. Actinomycorrhizal symbiosis

Unit III

7 Lectures

Mycorrhizal association: type, colonization of mycorrhiza and contribution in nutrient uptake. taxonomy, occurrence and distribution, phosphorus nutrition, growth and yield–its influence on growth and yield of crop plants.

Unit IV

7 Lectures

Strategies of Mass multiplication and packaging; Quality standard for bio-fertilizers; Different methods of application of bio-fertilizers, Methods of quality control assessment in respect of bio-fertilizers; Registration of bio-fertilizers.

Paper Code: BOTS-106(P)

Paper Title: Biofertilizers (Practical)

Credit: 2

1. Study of bacteria and cyanobacteria (used in biofertilizers) from temporary mounts /permanent slides.
2. Study of *Rhizobium* from root nodules of leguminous plants by Gram staining method
3. Morphological study and isolation of *Anabaena* from *Azolla* leaf
4. Observation of different mycorrhizae from temporary mounts/permanent slides of mycorrhizal roots
5. Familiarity of different commercial biofertilizer formulations
6. Methods for field application of biofertilizers
7. Quality control of bio-fertilizers: ISI standards specified and estimating the viable bacterial count in carrier based bio-fertilizers,
8. Preparation of proposal of bio-fertilizers production unit

Suggested readings

1. Anonymous 2016. Proceedings of Workshop on Biofertilizers. New Delhi. Delhi: Zakir Husain Delhi College
2. Kumaresan, V. 2005. Biotechnology. New Delhi, Delhi: Saras Publication.
3. Sathe, T.V. 2004. Vermiculture and Organic Farming. New Delhi, Delhi: Daya publishers.
4. Subha Rao, N.S. 2000. Soil Microbiology. New Delhi, Delhi: Oxford & IBH Publishers.
5. Subba Rao, N.S. 1993. Biofertilizers in Agriculture and Forestry. Oxford and IBH. Publ. Co., New Delhi.
6. Vayas,S.C, Vayas, S., Modi, H.A. 1998. Bio-fertilizers and organic Farming. Nadiad, Gujarat: Akta Prakashan

Skill Enhancement Course

Paper Code: BOTS-107

Paper Title: Mushroom Cultivation (Theory)

Credit: 2

Unit I: **7 lectures**

Introduction, History. Nutritional and medicinal value of edible mushrooms; Poisonous mushrooms; Types of edible mushrooms available in India (with local emphasis)- *Volvariella volvacea*, *Pleurotus* spp., *Agaricus bisporus*, *Schizophyllum commune*, *Auricularia* spp., *Lentinula edodes*, *Ganoderma* spp.

Unit II: **9 lectures**

Cultivation Technology : Infrastructure: substrates (locally available), polythene bag, vessels, Inoculation hook, inoculation loop, low cost stove, sieves, culture rack, mushroom unit (Thatched house) water sprayer, tray, small polythene bag. Pure culture: Media preparation, preparations of spawn, multiplication. Mushroom bed preparation - paddy straw, sugarcane trash, maize straw, banana leaves. Factors affecting the mushroom bed preparation- Low cost technology; Composting technology in mushroom production.

Unit III: **7 lectures**

Cultivation methods for *Pleurotus*, *Volvariella*, *Lentinula* and *Agaricus*; Methods of harvesting, processing, grading and packing; Short-term storage (Refrigeration – up to 24 hours); Long term storage (canning, pickels, papads), drying, storage in salt solutions; Use of spent mushroom in vermin-composting and in organic farming.

Unit IV: **7 lectures** Disease control and pest management: types of diseases and pests of mushrooms and their control methods; Mushroom Research Centres- National level and Regional level. Marketing and cost economics of mushroom culture- Cost benefit ratio; Marketing in India and abroad; Export Value.

Paper Code: BOTS-108(P)

Paper Title: Mushroom Cultivation (Practical)

Credit: 2

1. Principle and functioning of instruments used in the various techniques.
2. Preparation of various types of media.
3. Preparation of spawn.
4. Study of edible and poisonous mushrooms
5. Study of diseases of mushroom.
6. Nutritional and market value of mushroom
7. Centres of mushroom.
8. Techniques for the cultivation of *Agaricus*, *Pleurotus* and *Ganoderma*.
9. Visit to Institutes and cultivation centres.

Suggested Readings

1. Bahl, N. 2015. Hand book of Mushrooms, IV Edition, Oxford & IBH Publishing Co Ltd., New Delhi
2. Kannaiyan, S. and Ramasamy, K. 1980. A Hand Book of Edible Mushroom. Today & Tomorrows printers & publishers, New Delhi

3. Marimuthu, T., Krishnamoorthy, A.S., Sivaprakasam, K. and Jayarajan. R. 1991. Oyster Mushrooms, Department of Plant Pathology, Tamil Nadu Agricultural University, Coimbatore.
4. Swaminathan, M. 1990. Food and Nutrition. Bappco, The Bangalore Printing and Publishing Co. Ltd., No. 88, Mysore Road, Bangalore - 560018.
5. Tewari, P. and Kapoor, S.C.,1988. Mushroom cultivation, Mittal Publications, Delhi.

Skill Enhancement Course

Paper Code: BOTS-109

Paper Title: Fermentation Technology (Theory)

Credit: 2

Unit I

8 Lectures

History, Scope and Development of Fermentation technology; Isolation and screening of industrially important microorganisms – primary and secondary screening; Maintenance of Strains; Strain improvement: Mutant selection and Recombinant DNA technology

Unit II

6 Lectures

Natural and Synthetic media; Basic components of a media (Carbon sources; Nitrogen sources; Vitamins; Minerals; Anti-foaming agents); Role of buffers in media; Process of aeration, and agitation.

Unit III

8 Lectures

Basic designs of Fermentor; Type of fermentors: Waldhof, Tower, Deepjet, Cyclone column, Packed tower and airlift fermenter; Scale up study and Product development; Down-stream processing and Product recovery; Regulation and safety

Unit IV

6 Lectures

Production of alcohol; Organic acid – Citric acid; Antibiotic – Penicillin, Amino acid – Glutamic acid; Vitamin – B1; Single Cell Protein (SCP).

Paper Code: BOTS-110(P)

Paper Title: Fermentation Technology (Practical)

Credit: 2

1. Isolation of antibiotic producing microorganisms from soil
2. Isolation of enzyme producing microorganisms from soil
3. Isolation of organic acid producing microorganisms from soil
4. Production of Alcohol
5. Production of Citric acid

Suggested readings

1. Bryce, E.M., Demain, T.C., Allman. A.R. 2006. Fermentation Microbiology and Biotechnology. Second Edition. CRC Press, USA.
2. Chen, H. 2013. Modern Solid State Fermentation: Theory and Practice. Springer Press, Germany
3. Lancini, G., Lorenzetti, R. 2014. Biotechnology of Antibiotics and other Bioactive Microbial Metabolites. Springer publications, Germany.
4. Pepler, H.J., Perlman, D. 2014. Microbial Technology: Fermentation Technology. Academic Press.
5. Smith, J.E. 2009. Biotechnology. Cambridge University Press.UK.
6. Stanbury, P.F., Whitaker, A., Hall, S.J., 2016. Principles of Fermentation Technology. Butterworth-Heinemann Press. UK.
7. Todaro, C.M., Henry C. Vogel, H.C., 2014. Fermentation and Biochemical Engineering Handbook. William Andrew Press. Norwich, NY.

Semester II

Core Course

Paper code: BOTC-201

Paper Title: Plant Systematics (Theory)

Credit: 4

Unit I: Plant systematics

15 lectures

Introduction to systematics; Plant identification, Classification, Nomenclature. Evidence from palynology, cytology, phytochemistry [Alkaloids, Phenolics, Glucosides, terpenes and Semantides (in brief)] and molecular data (cp.DNA, mt-DNA, nuclear DNA, PCR amplification, sequence data analysis). Field inventory; Importance of Herbarium; Important herbaria and botanical gardens of the world and India; Virtual herbarium; E-flora; Documentation: Flora, Monographs, Journals; Keys: intended (yolked) and bracketed keys. Phenetics vs. Cladistics.

Unit II: Botanical Nomenclature and System of Classification

15 lectures

Principles and rules (ICN); Ranks and names; Typification, author citation, valid publication, rejection of names, principle of priority and its limitations; Names of hybrids.

System of classification: Natural system of classification (Bentham and hooker), Takhtajan classification of Angiosperms, Principles of Angiosperm Phylogeny Group (APG IV) classification.

Unit III: Biometrics, Numerical Taxonomy and Cladistics

15 lectures

Characters; Variations; OTUs, character weighting and coding; Cluster analysis; Phenograms, cladograms (definitions and differences).

Unit IV: Taxonomic hierarchy and Phylogenetic Systematics

15 lectures

Taxonomic Hierarchy: Concept of taxa (family, genus, species); Categories and taxonomic hierarchy; Species concepts (biological, morphological, evolutionary).

Phylogenetic Systematics: Terms and concepts (primitive and advanced, homology and analogy, parallelism and convergence, monophyly, paraphyly, polyphyly, clades. synapomorphy, symplesiomorphy, apomorphy. Origin and evolution of angiosperms; Coevolution of angiosperms and animals; Methods of illustrating evolutionary relationship (phylogenetic tree, cladogram).

Paper code: BOTC-202(P)

Paper Title: Plant Systematics (Practical)

Credit: 2

1. Study of vegetative and floral characters of the following families (Description, V.S. flower, section of ovary, floral diagram/s, floral formul/e and systematic position

according to Bentham and Hooker's system of classification) Ranunculaceae-
Ranunculus, Delphinium
 Brassicaceae- *Brassica, Alyssum/ Iberis*
 Fabaceae- *Calliandra/Prosopis/ Acacia, Cajanus/Sesbania, Cassia*
 Myrtaceae- *Eucalyptus, Callistemon* Umbelliferae-*Coriandrum/ Anethum/*
Foeniculum Asteraceae- *Sonchus/ Launaea, Veronia/ Ageratum, Elipta/*
Tridax
 Solanaceae- *Solanum nigrum, Withania sominifera* Lamiaceae- *Salvia/Ocimum*
 Euphorbiaceae-*Euphorbia hirta/ E.milli, Jatropha* Liliaceae- *Asphodelus/*
Lilium/ Allium Poaceae- *Triticum/ Hordeum/ Avena/ Poa*
 Malvaceae-*Abutilon/ Hibiscus/ Sida* Caryophyllaceae-*Stellaria/*
Dianthus/Spergulla Rubiaceae- *Hamelia patens / Ixora / Oldenlandia sp.*
 Apocyanaceae- *Catharanthus roseus/Cascabala thevitea/Tabernemontana sp.*
 Asclepediaceae- *Calotropis procera*
 Moraceae- *Morus alba*
 Chenopodiaceae- *Chenopodium alba*
 Cannaceae- *Canna indica*

Ten families should be selected out of the given list of nineteen families with available seasonal species of genus indicated in parenthesis.

2. Field visit (local)- Subject to grant funds from the University
3. Mounting of a properly dried and pressed specimen of any wild plant on herbarium sheet (to be submitted with the record book).

Suggested readings

1. Gupta R.2011 (Ed.) Plant Taxonomy: past, present, and future. New Delhi: The Energy and resources Institute (TERI).
2. Hall, B.G. 2011. Phylogenetic Trees Made Easy: A How-To Manual. Sinauer Associates, Inc. USA
3. Raven, F.H., Evert, R. F., Eichhorn, S.E. 1992. Biology of Plants. W.H. Freeman and Company. New York, NY.
4. Simpson, M.G. 2010. Plant Systematics. Elsevier Academic Press, San Diego, CA, U.S.A.
5. Singh, G. 2012. Plant Systematics: Theory and Practice, 3rd edition. Oxford and IBH Pvt. Ltd. New Delhi.
6. Stace, C.A 1989 Plant Taxonomy and Biosystematics 2nd edition. Cambridge University Press, NY USA.
7. Stuessy, Tod F. 2009 Plant Taxonomy: The systematic evaluation of comparative data - 2nd edition. Columbia University Press
8. Walter S. Judd, et.al. 2015 Plant Systematics : A Phylogenetic Approach 4th Edition Sinauer Associates , Oxford University Press. USA.

9. <http://www.mobot.org/MOBOT/research/APweb/>
10. Any local/state/regional flora published by BSI or any other agency

Core Course

Paper Code: BOTC – 203

Paper Title: Biomolecules and Cell Biology (Theory)

Credit – 4

Unit I: Bioenergetics and Enzymes 15 lectures Laws of thermodynamics, concept of free energy, endergonic and exergonic reactions, coupled reactions, redox reactions. ATP: structure, its role as an energy currency molecule. Structure of enzyme: holoenzyme, apoenzyme, cofactors, coenzymes and prosthetic group;

Classification of enzymes; Features of active site, substrate specificity, mechanism of action (activation energy, lock and key hypothesis, induced - fit theory), Michaelis – Menten equation, Lineweaver–Burk equation, and factors affecting enzyme activity (in brief).

Unit II: Biomolecules 15 lectures

Types and significance of chemical bonds; Structure and properties of water; pH and buffers. Carbohydrates: Nomenclature and classification; Role of monosaccharides (glucose, fructose, sugar alcohols – mannitol and sorbitol); Disaccharides (sucrose, maltose, lactose), Oligosaccharides and polysaccharides (structural-cellulose, hemicelluloses, pectin, chitin, mucilage; storage – starch, inulin). Lipids: Definition and major classes of storage and structural lipids; Fatty acids structure and functions; Structural lipid: Triacylglycerols structure, functions and properties Phosphoglycerides. Proteins: Structure of amino acids; Levels of protein structure-primary, secondary, tertiary and quaternary; Protein denaturation and biological roles of proteins. Nucleic acids: Structure of nitrogenous bases; Structure and function of nucleotides; Types of nucleic acids; Structure of A, B, Z types of DNA; Types of RNA; Structure of tRNA.

Unit III: Cell Biology - I 15 lectures

Cell as a unit of structure and function; Characteristics of prokaryotic and eukaryotic cells; Plant and animal cells; Origin of eukaryotic cell (Endosymbiotic theory). Chemistry, structure and function of Plant cell wall. Overview of membrane function; fluid mosaic model; Chemical composition of membranes; Membrane transport – Passive, active and facilitated transport, endocytosis and exocytosis. Nucleus: Structure-nuclear envelope, nuclear pore complex, nuclear lamina, molecular organization of chromatin; nucleolus. Phases of eukaryotic cell cycle, mitosis and meiosis; Regulation of cell cycle - checkpoints and regulation; role of protein kinases.

Unit IV: Cell Biology – II 15 lectures

Cytoskeleton: Role and structure of microtubules, microfilaments and intermediary filament; Intracellular trafficking. Chloroplast, mitochondria and peroxisomes: Structural organization; Function; Semiautonomous nature of mitochondria and chloroplast. Lysosomes and Vacuoles. Endomembrane system: Endoplasmic Reticulum – Types and Structure. Golgi

Apparatus – organization, protein glycosylation, protein sorting and export from Golgi
ApparatusSignal Transduction: Receptors and primary and secondary signal transduction

Paper Code: BOTC – 204(P)

Paper Title: Biomolecules and Cell Biology (Practical)

Credit – 2

1. Qualitative tests for carbohydrates, reducing sugars, non-reducing sugars, lipids and proteins.
2. Study of plant cell structure with the help of epidermal peel mount of Onion/ Rheo/ Crinum
3. Demonstration of the phenomenon of protoplasmic streaming in Hydrilla leaf.
4. Separate chloroplast pigments by paper chromatography.
5. Study of cell and its organelles with the help of electron micrographs.
6. Study the phenomenon of plasmolysis and deplasmolysis.
7. Demonstrate the activity of any two enzymes (Urease, Amylase, and Catalase).
8. Study the effect of organic solvent and temperature on membrane permeability.
9. Study different stages of mitosis and meiosis.
10. Separation of protein by Electrophoresis. (Only demonstration to class by the instructor).

Suggested readings

1. Alberts, B., Johnson, A.D., Lewis, J., Morgan, D., Raff, M., Roberts, K., Walter, P. 2014. Molecular Biology of Cell. 6th Edition. WW. Norton & Co.
2. Becker, W.M., Kleinsmith, L.J., Hardin. J. and Bertoni, G. P. 2009. The World of the Cell. 7th edition. Pearson Benjamin Cummings Publishing, San Francisco.
3. Berg, J.M., Tymoczko, J.L. and Stryer, L. 2011. Biochemistry, W.H.Freeman and Company
4. Campbell, M.K. 2012. Biochemistry, 7th ed., Published by Cengage Learning.
5. Campbell, P.N. and Smith, A.D. 2011. Biochemistry Illustrated, 4th ed., Published by Churchill Livingstone
6. Cooper, G.M. and Hausman, R.E. 2009. The Cell: A Molecular Approach. 5th edition. ASM Press & Sunderland, Washington, D.C.; Sinauer Associates, MA.
7. Cooper., G.M. 2015. The cell: A Molecular Approach. 7th Edition. Sinauer Associates.
8. Hardin, J., Becker, G., Skliensmith, L.J. 2012. Becker's World of the Cell. 8th edition. Pearson Education Inc. U.S.A
9. Iwasa,J, Marshall , W. 2016. Karp's Cell and Molecular Biology; Concepts and experiments.
10. Karp, G. 2010. Cell Biology, John Wiley & Sons, U.S.A. 6th edition.
11. Nelson, D.L. and Cox, M.M. 2008. Lehninger Principles of Biochemistry, 5th Edition. W.H. Freeman and Company.
12. Reven, F.H., Evert, R.F., Eichhorn, S.E. 1992. Biology of Plants. New York, NY: W.H.Freeman and Company.

13. Tymoczko, J.L., Berg, J.M. and Stryer, L. 2012. Biochemistry: A short course, 2nd ed., W.H.Freeman.

Skill Enhancement Course

Paper code: BOTS-205

Paper Title: Botanical Garden and Landscaping (Theory)

Credit: 2

Course Content

Unit I

8 lectures

Principles of gardening, garden components, adornments, lawn making, methods of designing rockery, water garden, etc. Special types of gardens, their walk-paths, bridges, constructed features. Greenhouse. Special types of gardens, trees, their design, values in landscaping, propagation, planting shrubs and herbaceous perennials. Importance, design values, propagation, plating, climbers and creepers, palms, ferns, grasses and cacti succulents.

Unit II

7 lectures

Flower arrangement: importance, production details and cultural operations, constraints, postharvest practices. Bioaesthetic planning, definition, need, round country planning, urban planning and planting avenues, schools, villages, beautifying railway stations, dam sites, hydroelectric stations, colonies, river banks, planting material for play grounds.

Unit III

8 lectures

Vertical gardens, roof gardens. Culture of bonsai, art of making bonsai. Parks and public gardens. Landscape designs, Styles of garden, formal, informal and free style gardens, types of gardens, Urban landscaping, Landscaping for specific situations, institutions, industries, residents, hospitals, roadsides, traffic islands, damsites, IT parks, corporate.

Unit IV

7 lectures

Establishment and maintenance, special types of gardens, Bio-aesthetic planning, ecotourism, theme parks, indoor gardening, therapeutic gardening, non-plant components, water scaping, xeriscaping, hardscaping; Computer Aided Designing (CAD) for outdoor and indoorscaping Exposure to CAD (Computer Aided Designing)

Paper code: BOTS-206(P)

Paper Title: Botanical Garden and Landscaping (Practical)

Credit: 2

1. Field trips: Field visit to regional/national Botanical Garden.
2. Identification of trees, shrubs and other herbaceous vegetation,
3. Prepare beds for growing nursery for herbs, shrubs and trees.
4. Count the number of types of animals, birds, and insects in the garden
5. Identification of pathogenic and non-pathogenic diseases of garden plants and grasses
6. More Practical may be added depending on the local habitats and available facilities
7. Try to grow herbs hydroponically

References

1. Berry, F. and Kress, J. (1991). Heliconia: An Identification Guide . Smithsonian Books.
2. Butts, E. and Stensson, K. (2012). Sheridan Nurseries: One hundred years of People, Plans, and Plants. Dundurn Group Ltd
3. Russell, T. (2012). Nature Guide: Trees: The world in your hands (Nature Guides).

Skill Enhancement Course

Paper code: BOTS-207

Paper Title: Nursery and Gardening (Theory)

Credit: 2

Course Content

Unit I

7 lectures

Nursery: definition, objectives and scope and building up of infrastructure for nursery, planning and seasonal activities - Planting - direct seeding and transplants.

Unit II

7 lectures

Seed: Structure and types - Seed dormancy; causes and methods of breaking dormancy Seed storage: Seed banks, factors affecting seed viability, genetic erosion - Seed production technology - seed testing and certification.

Unit III

8 lectures

Vegetative propagation: air-layering, cutting, selection of cutting, collecting season, treatment of cutting, rooting medium and planting of cuttings - Hardening of plants - green house - mist chamber, shed root, shade house and glasshouse.

Unit IV

8 lectures

Gardening: definition, objectives and scope - different types of gardening - landscape and home gardening - parks and its components - plant materials and design – computer applications in landscaping - Gardening operations: soil laying, manuring, watering, management of pests and diseases and harvesting. Transplanting of seedlings - Study of cultivation of different vegetables: cabbage, brinjal, lady's finger, onion, garlic, tomatoes, and carrots - Storage and marketing procedures.

Paper code: BOTS-208(P)

Paper Title: Nursery and Gardening (Practical)

Credit: 2

1. To study the process of sowing seeds in nursery
2. To list the various resources required for the development of nursery
3. To study the different forms of sowing and growing plants
4. To study the process of Vegetative propagation
5. Listing of garden plants
6. To study computer applications in landscaping

7. To examine the cultivation of different vegetables and growth of plants in nursery
8. To study cold storage models for vegetables
9. To visit nearby local Nursery and record the plant list

Suggested readings

1. Bose T.K. & Mukherjee, D. (1972). Gardening in India, Oxford & IBH Publishing Co., New Delhi.
2. Sandhu, M.K. (1989) Plant Propagation, Wile Eastern Ltd., Bengaluru.
3. Kumar, N. (1997) Introduction to Horticulture, Rajalakshmi Publications, Nagercoil. Edmond Musser & Andres, Fundamentals of Horticulture, McGraw Hill Book Co., New Delhi.
4. Agrawal, P.K. (1993). Hand Book of Seed Technology, Dept. of Agriculture and Cooperation, National Seed Corporation Ltd., New Delhi.
5. Janick Jules (1979). Horticultural Science. (3rd Ed.), W.H. Freeman and Co., SanFrancisco, USA.

Skill Enhancement Course

Paper code: BOTS-209

Paper Title: Floriculture (Theory)

Credit: 2

Course Content

Unit-I 8 lectures Introduction: History of gardening; Importance and scope of floriculture and landscape gardening.

Nursery Management and Routine Garden Operations: Sexual and vegetative methods of propagation; Soil sterilization; Seed sowing; Pricking; Planting and transplanting; Shading; Stopping or pinching; Defoliation; Wintering; Mulching; Topiary; Role of plant growth regulators.

Unit-II

6 lectures

Ornamental Plants: Flowering annuals; Herbaceous perennials; Divine vines; Shade and ornamental trees; Ornamental bulbous and foliage plants; Cacti and succulents; Palms and Cycads; Ferns and Selaginellas; Cultivation of plants in pots; Indoor gardening; Bonsai.

Unit-III

8 lectures

Principles of Garden Designs: English, Italian, French, Persian, Mughal and Japanese gardens; Features of a garden (Garden wall, Fencing, Steps, Hedge, Edging, Lawn, Flower beds, Shrubbery, Borders, Water garden). Some Famous gardens of India.

Landscaping Places of Public Importance: Landscaping highways and Educational institutions.

Unit-VI

8 lectures Commercial Floriculture: Factors affecting flower production;

Production and packaging of cut flowers; Flower arrangements; Methods to prolong vase life;

Cultivation of Important cut flowers (*Carnation, Aster, Chrysanthemum, Dahlia, Gerbera, Gladiolous, Marigold, Rose, Liliium, Orchids*). Diseases and pests of ornamental plants.

Paper code: BOTS-210(P)

Paper Title: Floriculture (Practical)

Credit: 2

1. Identification of commercially important floricultural crops.
2. Preparation of flower bed.
3. Seed sowing and transplantation methods.
4. Propagation by cutting, layering, budding and grafting.
5. Patterns of flower arrangement in vase.
6. Use of chemicals and other compounds for prolonging the vase life of cut flowers.
7. Drying and preservation of flowers.
8. Study of disease and pests of ornamental plants.
9. Garden designing and hedge preparation methods.
10. Field visit to flower gardens.

Suggested readings

1. Randhawa, G.S., Mukhopadhyay, A. (1986). Floriculture in India. New York, NY: AlliedPublishers.
2. Adams, C., M. Early and J. Brrok (2011). Principles of Horticulture. Routledge, U.K.
3. A.K.Singh.2006. Flower crops, cultivation and management. New India publishing agency, Pitampura, New Delhi.
4. T.K. Bose, L.P. Yadav, P. Patil, P. Das and V.A. Partha Sarthy. 2003. Commercial Flowers. Partha Sankar Basu, Nayaudyog, 206, Bidhan Sarani, Kolkata.
5. S.K. Bhattacharjee and L.C. De. 2003. Advanced Commercial Floriculture. Aavishkar Publishers,Distributors, Jaipur.
6. Dewasish Choudhary and Amal Mehta. 2010. Flower crops cultivation and management. Oxford book company Jaipur, India. Randhawa,
7. G.S. Amitabha Mukhopadhyay, 2004. Floriculture in India. Allied Publishers Pvt. Ltd.
8. Arora, J.S. 2006. Introductory Ornamental Horticulture. Kalyani Publishers, Ludhiana.
9. Bhattacharjee, S.K. Advanced Commercial Floriculture. Aavishkar Publishers Distributors,Jaipur.
10. Sheela, V.L. 2008. Flower for trade. New India Publishing Agency, Pitampura, NewDelhi-110088.
11. Abhinov Kumar. 2000. Production Technology of Ornamental Crops, Medicinal Plantsand Landscaping. Kalyani Publishers, New Delhi.

Semester- III

Core Course

Paper Code: BOTC - 301

Paper Title: Plant Metabolism (Theory)

Credit: 4

Unit I: Concept of Metabolism and Photosynthetic pigments **10 lectures**

Introduction, anabolic and catabolic pathways, regulation of metabolism; enzyme inhibition (competitive, non-competitive and uncompetitive); role of regulatory enzymes (allosteric regulation and covalent modulation, isozymes and alloenzymes); Historical background, role of photosynthetic pigments (chlorophylls and accessory pigments - No structural details), antenna molecules and reaction centres,

Unit II: Carbon Assimilation, Metabolism and Oxidation **20 lectures**

Photochemical reactions, PSI, PSII, photosynthetic electron transport, photophosphorylation, Q cycle, CO₂ Reduction/Carbon Assimilation: C3, C4 and CAM pathways; photorespiration; Factors affecting CO₂ reduction. Synthesis and catabolism of sucrose and starch. Carbon Oxidation: Glycolysis and its regulation, fate of pyruvate- aerobic and anaerobic respiration and fermentation, oxidative decarboxylation of pyruvate, TCA cycle, oxidative pentose phosphate pathway, amphibolic role, anaplerotic reactions, mitochondrial electron transport, oxidative phosphorylation, cyanide-resistant respiration, factors affecting respiration.

Unit III: ATP-Synthesis **12 lectures**

Mechanism of ATP synthesis, substrate level phosphorylation, chemiosmotic mechanism (oxidative and photophosphorylation), ATP synthase, Boyers conformational model, Racker's experiment, Jagendorf's experiment; role of uncouplers.

Unit IV: Lipid and Nitrogen Metabolism, Mechanism of Signal Transduction **18 lectures**

Synthesis and breakdown of triglycerides, β -oxidation, glyoxylate cycle, gluconeogenesis and its role in mobilisation of lipids during seed germination, α oxidation. Nitrate Assimilation, Biological nitrogen fixation (examples of legumes and non-legumes); Physiology and biochemistry of nitrogen fixation; Ammonia assimilation (GS-GOGAT), reductive amination and transamination. Receptor – ligand interactions; Secondary messenger concept, Calciumcalmodulin, MAP kinase cascade.

Paper Code: BOTC-302 (P)

Paper Title: Plant Metabolism (Practical)

Credit: 2

1. Solvent partitioning of photosynthetic pigments.
2. Experimental demonstration of Hill's reaction.
3. To study the effect of light intensity on the rate of photosynthesis.

4. Effect of carbon dioxide on the rate of photosynthesis.
5. To compare the rate of respiration in different parts of a plant.
6. To demonstrate activity of Nitrate reductase in germinating leaves of different plant sources.
7. To study the activity of lipases in germinating oilseeds and demonstrate mobilization of lipids during germination.
8. Demonstration of fluorescence by isolated chlorophyll pigments.
9. Demonstration of absorption spectrum of photosynthetic pigments.
10. Chemical separation of photosynthetic pigments.
11. Demonstration of respiratory quotient (RQ).
12. To study the activity of catalase enzyme and effect of heavy metal and pH on enzyme activity.

Suggested readings

1. Bhatla, S.C., Lal, M.A. 2018. Plant Physiology, Development and Metabolism. Singapore: Springer.
2. Buchanan, B., Gruissem W., Jones, R.L. (Eds) 2015 Biochemistry and Molecular Biology of Plants. Second Edition. Paper back. Wiley-Blackwell.
3. Harborne, J.B. 1973. Phytochemical Methods. John Wiley & Sons. New York Hopkins, W.G. and Huner, A. 2008. Introduction to Plant Physiology. 4th edition. John Wiley and Sons.U.S.A.
4. Heldt, H.W., B. Piechulla, B. 2019. Plant Biochemistry. 4th Edition. Paperback. Academic Press.
5. Jain V.K.2016. Fundamentals of Plant Physiology 18th edition. New Delhi, India: S. Chand & Company Pvt. Ltd.
6. Jones, R.,Ougham, H., Thomas,H.,Waaland, S. 2013. The molecular life of plants. Chichester, England: Wiley-Blackwell.Taiz, L., Zeiger, E., MØller, I.M. and Murphy, A 2015. Plant Physiology and Development. 6th edition. Sinauer Associates Inc. USA.
7. Nelson, D.L., Cox, M.M. 2017. Lehninger Principle of Biochemistry, 7th edition. New York, NY: W.H. Freeman, Macmillan learning.
8. Salisbury F.B., Ross C.W. 2006. Plant Physiology 4th edition. Delhi, India: CBS Publishers and Distributors.

Core Course

Paper Code: BOTC-303

Paper Title: Ecology and Phytogeography (Theory)

Credit: 4

Unit I: Introduction

15 lectures

Brief History, Basic concepts; Levels of organization; Inter- relationships between the living world and the environment; Ecosystem dynamics and homeostasis; Soil formation, types and profile development, physical and chemical properties of soil.

Unit II: Population ecology and plant adaptations

15 lectures

Distribution and characteristics of populations; Population growth and dynamics; Ecological Speciation (Ecads, ecotypes, ecospecies, etc.); Mortality natality; r and k selection; Types of biotic interactions, Inter and intra-specific competition

Unit III: Ecosystem and plant communities

20 lectures

Structure; Types; Processes; Trophic organization; Food chains and Food webs; Ecological pyramids; Principles and modes of energy flow, Production and productivity, biogeochemical cycling; Ecological efficiencies; Concept of ecological amplitude; Habitat and Ecological niche; Community characters; Ecotone and edge effect; Methods to studying vegetation; Concepts of plant succession and climax.

Unit IV: Phytogeography

10 lectures

Phytogeographic regions of the world and India; Static and dynamic phytogeography; Continental drift; Theory of tolerance; Endemism; Major terrestrial biomes; Vegetation of N.E. India with special reference to Manipur.

Paper Code: BOTC-304(P)

Paper Title: Ecology and Phytogeography (Practical)

Credit: 2

1. Familiarization of instruments used to measure microclimatic variables: Soil moisture meter, conductivity meter, maximum and minimum thermometer, anemometer, hygrometer, rain gauge, lux meter etc.
2. Determination of pH of soil and water samples
3. Analysis for carbonates, chlorides, nitrates, sulphates, organic matter and base deficiency of soil samples by field testing kits.
4. Determination of soil organic matter rapid titration method.
5. Determination of dissolved oxygen of water samples from polluted and unpolluted sources.
6. Study of morphological adaptations of hydrophytes and xerophytes.
7. Determination of minimal quadrat size for the study of herbaceous vegetation by species area curve method.
8. Quantitative analysis of herbaceous vegetation for frequency and comparison with Raunkiaer's frequency distribution.
9. Quantitative analysis of herbaceous vegetation for density and abundance
10. Field visit to familiarize students with different biomes, ecosystems and vegetation.

Suggested readings

1. Ambasht, R.S, and Ambasht, N.K. 2008. A text book of Plant Ecology, CBS Publishers & Distributors PVT. LTD. 14th Edition.
2. Kormondy, E.J. 2017. Concepts of Ecology. India:Pearson India Education Services Pvt. Ltd. 4th edition.

3. Majumdar, R. and Kashyap, R. 2019. Practical Manual of Ecology and Environmental Science, New Delhi, India: Prestige Publishers. Odum, E.P. 2005. Fundamentals of Ecology. New Delhi, India: engage Learning India Pvt. Ltd., 5th edition.
4. Sharma, P.D. 2015. Ecology and Environment. Meerut, India: Rastogi Publications. 12th edition.
5. Singh, J.S., Singh, S.P., Gupta, S.R. 2014. Ecology, Environmental Science and Conservation. New Delhi, India: S. Chand.

Core Course

Paper Code: BOTC-305

Paper Title: Genetics and Cytogenetics (Theory)

Credit: 4

Unit I: Principles of Genetics and Biology of Inheritance 15 lectures

Mendelism: History; Mendel's Laws of inheritance; Chromosome theory of inheritance and linkage; Incomplete dominance and codominance; Interaction of Genes; Multiple alleles, Lethal alleles, Epistasis, Pleiotropy, Recessive and Dominant traits, Penetrance and Expressivity, Mendelian segregation and gene interaction: Numericals; Polygenic inheritance; Mitosis and Meiosis in plants, animal and human; Cell cycle and cell division.

Unit II: Extra-nuclear Inheritance, Linkage, Crossing over and Chromosome mapping 15 lectures

Determining non-Mendelian Inheritance; Maternal effects and cytoplasmic inheritance; Chloroplast mutation: Variegation in Four O'clock plant; Mitochondrial mutations in yeast; Maternal effects-shell coiling in snail; Infective heredity- Kappa particles in Paramecium. Linkage and crossing over; Cytological basis of crossing over; Recombination frequency, two factor and three factor crosses; Interference and coincidence; Linkage and Gene mapping, and numericals based on gene mapping;

Unit III: Variation in Chromosome Number and Structure, Mutations 15 lectures

Chromosome morphology and Karyotype concept, Deletion, Duplication, Inversion, Translocation, Position effect; Euploidy, Aneuploidy and Amphiploidy and their implications, FISH and GISH in chromosome and genome identification. Types of mutations; Molecular basis of Mutations; Induction of mutations and Mutagens – physical and chemical (Base analogs, deaminating, alkylating and intercalating agents); Detection of mutations: CIB method. Role of Transposons in mutation. DNA repair mechanisms.

Unit IV: Fine Structure of Gene, Gene Interaction, Population and Evolutionary Genetic 15 lectures

Evolution of Gene Concept - Classical vs molecular concepts of gene : One gene one character; One gene-one enzyme, one gene-one polypeptide hypothesis and beyond; Cistrans complementation test for functional allelism and gene as unit of function, mutation and recombination, non-coding RNA. Concept of sex determination and Sex chromosomes;

Patterns of Sex determination in plants and animals (human, Drosophila and other animals) ; Sex-linked, sex-limited and sex-influenced characters; Dosage compensation. Allele frequencies, Genotype frequencies, Hardy-Weinberg Law, role of natural selection, mutation, genetic drift. Genetic variation and Speciation.

Paper Code: BOTC-306(P)

Paper Title: Genetics and Cytogenetics (Practical)

Credit: 2

1. Mitosis, and study of chromosome morphology through squash preparation, including effect of chemicals on mitosis.
2. Meiosis and study of chiasma frequency through temporary squash preparation.
3. Laws through seed ratios. Laboratory exercises in probability and chi-square.
4. Chromosome mapping using point test cross data.
5. Pedigree analysis for dominant and recessive autosomal and sex linked traits.
6. Incomplete dominance and gene interaction through seed ratios (9:7, 9:6:1, 13:3, 15:1, 12:3:1, 9:3:4).
7. Blood Typing: ABO groups & Rh factor.
8. Study of aneuploidy: Down's, Klinefelter's and Turner's syndromes.
9. Photographs/Permanent Slides showing Translocation Ring, Laggards and Inversion Bridge.
10. Study of human genetic traits: Sickle cell anemia, Xeroderma Pigmentosum, Albinism, red-green Color blindness, Widow's peak, Rolling of tongue, Hitchhiker's thumb and Attached earlobe.
11. To test PTC tasting ability in a random sample and calculate gene frequencies for the taster and non-taster alleles.
12. Identification of inactivated X chromosome as Barr body and drumstick.

Suggested readings

1. Gardner, E.J., Simmons, M.J., Snustad, D.P. (1991). Principles of Genetics. 8th edition. John Wiley & sons, India.
2. Griffiths, A.J.F., Wessler, S.R., Carroll, S.B., Doebley, J. (2010). Introduction to Genetic Analysis. 10th edition. W. H. Freeman and Co., U.S.A.
3. Gupta, P.K. (2018) Genetics. 5th Edition, Rastogi Publications, Meerut.
4. Hartl, D.L. and Jones, E.W. (1999). Essential Genetics, 2nd Edition, Jones and Barlett Publishers, Boston.
5. Jain, H.K. (1999). Genetics: Principles, Concepts and Implications. Science Pub Inc.
6. Klug, W.S., Cummings, M.R., Spencer, C.A. (2009). Concepts of Genetics. 9th edition. Benjamin Cummings, U.S.A.
7. Singh, R. J. (2016). Plant Cytogenetics, 3rd Edition. CRC Press, Boca Raton, Florida, USA.
8. Singh, R.J. (2017). Practical Manual on Plant Cytogenetics. CRC Press, Boca Raton, Florida, USA.
9. Snustad, D.P. and Simmons, M.J. (2010). Principles of Genetics. 5th edition. John Wiley & Sons Inc., India.

10. Strickberger, M.W. (1985) Genetics, 3rd Edition. Pearson Printice Hall (printed in India by Anand Sons).

Generic Elective Course

Paper Code: BOTG-301

Paper Title: Algal Biotechnology (Theory)

Credit: 4

Unit I

12 Lectures

Introduction to algal biotechnology: Resource potential of algae; commercial utility of algae. Algae as a source of food and feed; Algae as a source of pigments, fine chemicals, fuel and bio-fertilizers. Distribution of economically important algae in India.

Unit II

15 Lectures

Uses of the following algae: *Spirulina*, *Dunaliella*, *Haematococcus*, *Chlorella*, *Scenedesmus*, *Botryococcus*, *Porphyridium*, *Hypnea*, *Gracilaria*, *Gelidium*, *Gelidiella*, *Kappaphycus*, *Grateloupia*, *Sargassum*, *Turbinaria*, *Cystoseira*, *Laminaria*, *Macrocystis*, *Porphyra*, *Caulerpa* and *Ulva*. Algal production systems; Strain selection; Algal growth curve; Culture media; indoor cultivation methods and scaling up. Measurement of algal growth. Large-scale cultivation of algae. Evaporation and uniform dispersal of nutrients; Harvesting and drying of algae.

Unit III

15 Lectures

Algal production systems; Strain selection; Algal growth curve; Culture media; indoor cultivation methods and scaling up. Measurement of algal growth. Large-scale cultivation of algae. Evaporation and uniform dispersal of nutrients; Harvesting algae. Drying.

Unit IV

18 Lectures

Algal immobilization and its applications; Blue-green algal bio-fertilizer. Liquid seaweed fertilizer: Method of preparation and application. Biodiesel from algae: algae producing biodiesel; Advantages over other sources of biodiesel; Cultivation and extraction methods. Phycoremediation. Role of algae in nanobiotechnology. Algal culture collection centers in India and abroad and their importance; Centers pursuing algal research in India and their field of interest.

Generic Elective Course

Paper Code: BOTG-302(P)

Paper Title: Algal Biotechnology (Practical)

Credit: 2

1. Morphological study of the following algal forms - *Anabaena*, *Chlorella*, *Volvox*, *Chara*, *Ectocarpus*, *Sargassum*, *Polysiphonia* and *Gracilaria*.
2. Algal Biotechnology: Cultivation of algae in - Chu 10 medium (Demonstration only).

3. Study of economically important products obtained from algae
4. Field visit / trip to collect algal specimens - algae herbaria (5 numbers) to be submitted.
5. Visit to algal biotechnology laboratories.

Suggested readings

1. Barsanti, Laura and Paolo Gualtieri 2005 Algae-Anatomy, Biochemistry and Biotechnology. Taylor & Francis, London, New York.
2. Becker, E.W. 1994 Microalgae-Biotechnology and microbiology. Cambridge University Press.
3. Chandramohan, D. 2007. Prospects of Biodiesel from marine microorganisms. Proceedings of the National Workshop on BIODIESEL, Organised by School of Energy, Environment & Natural Resources, Madurai Kamaraj University, Madurai and Ahimsa Agri division, Chennai, 17th and 18th October, 2007.
4. Trivedi, P.C. 2001 Algal Biotechnology. Pointer publishers, Jaipur, India.
5. Venkataraman, L.V. and E.W. Becker 1985. Biotechnology and Utilization of Algae – The Indian Experience. Dept. Science and Technology, New Delhi and Central Food Research Institute, Mysore, India.

Generic Elective Course

Paper Code: BOTG-303

Paper Title: Intellectual Property Rights (Theory)

Credit: 4

Unit I: Introduction to Intellectual Property Right (IPR) 15 lectures

IPR - Concept and kinds, Copyright Act and IPR, Economic importance. IPR in India and world: Genesis and scope, IPR and WTO (TRIPS, WIPO). Objectives, Rights, Major International Instruments concerning Intellectual Property Rights: Paris Convention, 1883, the Berne Convention, 1886, the Universal Copyright Convention, 1952, the WIPO Convention, 1967, the Patent Act 1970 and its amendments, the TRIPS Agreement, 1994.

Unit II: Patents, Copyrights, Trademarks and Geographical Indications 15 lectures

Procedure of obtaining patents, working of patents. Infringement of patents, Copyrights: work protected under copyright laws, Rights, Transfer of Copyright, and Infringement. Trademarks: Objectives of trademarks, Types, Rights, Protection of goodwill, Infringement, Passing off, Defences, Domain name; Geographical Indications: Objectives, Justification, International Position, Multilateral Treaties, National Level, Indian Position

Unit III: Protection of Traditional Knowledge and Plant Varieties 15 lectures

Objective, Concept of Traditional Knowledge, Holders, Issues concerning, Bio prospecting and Bio-piracy, Alternative ways, Protectability, need for a Sui-Generis regime, Traditional Knowledge on the International Arena, at WTO, at National level, Traditional Knowledge Digital Library; Plant varieties – objectives, justification, Plant varieties protection in India, Rights of farmers, National gene bank; Benefit sharing. Protection of Plant Varieties and Farmers' Rights Act, 2001.

Unit IV: Information Technology Related IPR**15 lectures**

Computer Software and Intellectual Property, Database and Data Protection, Protection of Semiconductor chips, Domain Name Protection. Patenting Biotech Inventions: Objective, Applications, Concept of Novelty; Concept of inventive step, Microorganisms, and Moral Issues in Patenting Biotechnological inventions.

Paper Code: BOTG-304(P)**Paper Title: Intellectual Property Rights (Practical)****Credit: 2**

There are no experimental lab based Practical. However, the students are expected to prepare some project report based on the Success stories of Traditional Patents secured by India. Likewise, prepare a database for Indian products wherein the issue is still under consideration of the competent authorities. Prepare the dos and don'ts on Patents for Botanists.

Recommended Books:

1. Gopalakrishnan, N.S. and Agitha, T.G. (2009). Principles of Intellectual Property Eastern Book Company, Lucknow.
2. David Kitchin Q.C., Llewelyn, D., Mellor, J., Meade, R., Thomas Moody-Stuart, and D. Keeling, Jacob, R. (2005). Kerly's Law of Trade Marks and Trade Names (14th Edition) Thomson, Sweet & Maxwell.
3. Parulekar, A. and D' Souza, S. (2006). Indian Patents Law – Legal & Business Implications; Macmillan India Ltd.
4. Wadehra, B.L. (2000). Law Relating to Patents, Trade Marks, Copyright, Designs & Geographical Indications; Universal law Publishing Pvt. Ltd., India.
5. Narayanan, P. (2010). Law of Copyright and Industrial Designs; Eastern law House, Delhi.
6. N.K., Acharya.(2001).Text Book on Intellectual Property Rights: (Copyright, Trademark, Patent Design, Geographical Indications, Protection of New Plant Varieties & Farmers Rights and Protection of Biodiversity)
7. Gogia, SP. On Intellectual Property Rights (IPR). Hyderabad: Asia Law House
8. Bhandari, M.K. (2017). Law Relating to Intellectual Property Rights (IPR). Allahabad: U.P.: Central Law Publications.

Generic Elective Course**Paper Code: BOTG-305****Paper Title: Medicinal and Aromatic Plants (Theory)****Credit: 4****Unit I: Introduction to Medicinal and Aromatic Plants****15 Lectures**

Definition, History, Importance and future prospects of Medicinal and Aromatic Plants (MAPs), MAPs resources and diversity in India and Manipur, Medicinal Plants – past and present status in world and India. MAPs as industrial crops - constraints and remedial

measures, MAPs in Local and Traditional health care systems in India – Ayurveda, Siddha and Unani (Definition, history, origin and scope), MAPs as Non-timber forest products (NTFPs).

Unit II: Propagation, Collection and Conservation **15 Lectures** Survey and assessment of MAPs, Collection and processing of MAPs, Sustainability and threats to MAPs; concept of sustainable harvesting and management of MAPs; Conservation of Endemic and endangered MAPs, In situ conservation (Biosphere reserves, sacred groves, National Parks); Ex situ conservation (Botanic Gardens, Ethno medicinal plant Gardens); Propagation of Medicinal Plants - Objectives of the nursery, sowing, pricking, use of green house for nursery production, propagation through cuttings, layering, RET species and their conservation.

Unit III: Value and Utilisation of MAPs **15 Lectures**
Value and uses: Introduction and Use pattern of Medicinal and Aromatic Plants, Present scenario of MAPs based industry in India, MAPs based small scale industries in Manipur, Types of MAPs based consumer products present in Manipur market, Uses and Status of MAPs in Manipur. Utilization of MAPs as - raw materials, Ayurveda products, allopathic medicine, aroma therapy, essential oil and extracts, Industrial use of MAPs (Food, flavors, perfumes, cosmetics, spices and condiments, pharmaceuticals), Domestication potentiality of MAPs, Extraction methods Parts used for medicine of commercially valuable plants

Unit IV: Selected Medicinal and Aromatic Plants **15 Lectures**
Study of medicinal with respect to their Botanical name, vernacular name, parts used, active ingredients and uses -

Medicinal plants: Periwinkle, *Rauwolfia*, *Dioscorea*, *Withania*, Belladonna, *Cinchona*, Foxglove (*Digitalis*), *Tinospora*, Nux-vomica, *Solanum sps*, *Adhatoda sps*. *Artemesia*, *Aloe vera*. Turmeric

Study of aromatic plants with respect to their Botanical name, vernacular name, parts used, active ingredients; Extraction Methods, storage and utilisation of essential oils.

Aromatic Plants: Citronella and Lemon grass, Khus Khus grass (Vetiver), sweet flag (bach), Jasmine, Roses, Lavender, Eucalyptus, Ginger, *Mentha sps*, Camphor plant, Sandalwood, Patchouli (*Pogostemon*); Extraction Methods, storage and utilisation of essential oils.

Paper Code: BOTG-306(P)

Paper Title: Medicinal and Aromatic Plants (Practical)

Credit: 2

1. Collection and Identification of medicinal and aromatic plant found locally in Manipur and preparation of herbarium specimens.
2. Study of less known aromatic plants used in Manipur as foods and Sample collection of these plants.
3. Simple tests for the presence of alkaloids in plants.
4. Organoleptic study of some drug plants – Ginger, *Adhatoda*, *Rauwolfia*, *Cinchona*, Turmeric, Mints. *Solanum spp*.
4. Study of medicinal and aromatic plants - propagation techniques – harvesting and oil extraction of aromatic plants.

5. Study of locally prepared herbal tea, shampoo, face wash, any other lotions for different uses and medicine (Ingredients, method of preparation, doses storage),
6. Field visit, collection and preparation of herbarium specimens.
7. Visit to a commercial unit of essential oil extraction facility

Suggested readings

1. S.K. Bhattacharjee (2004). Hand Book of Aromatic Plants. Pointer Publishers, Jaipur.
2. S.K. Bhattacharjee (2020). Handbook of Medicinal Plants. Pointer Publishers, Jaipur.
3. L.D. Kapoor (2005). Handbook of Ayurvedic Medicinal Plants. CRC Press.
4. S.L. Kochhar (2007). Economic Botany in the Tropics. MacMillan India.
5. V.V. Sivarajan, V. V. and I. Balachandran (1994). Ayurvedic Drugs and their Plant Sources. Oxford & IBH.
5. Godagama Shantha (2004). The Handbook of Ayurveda. North Atlantic Books.
6. Thakur, R. S., Puri, H. S. and Husain, A. (1989). *Major medicinal plants of India*. Central Institute of Medicinal and Aromatic Plants, Lucknow, India.
7. Kala, C.P. (2010). Medicinal Plants of Uttarakhand: Diversity, Livelihood and Conservation. Biotech Books, Delhi.
8. Trivedi, P.C. (2009). Indian Medicinal Plants. Aavishkar Publishers & Distributors.
9. Samant, S.S., Dhar, U. and Palni, L. M. S. (1998). Medicinal Plants of Indian Himalaya: diversity distribution potential values. G. B. Pant Institute of Himalayan Environment and Development, Almora.
10. Kirtikar, K.R. and Basu, B.D. (1999). Indian Medicinal Plants (Vol 1- 4). International Book Distributors.
11. Sharma, R. (2013). Agro Techniques of Medicinal Plants. Daya Publishing House, Delhi.
12. Akerele, O., Heywood, V. and Synge, H. (1991). The Conservation of Medicinal Plants. Cambridge University Press.
13. Jain, S.K. and Jain, Vartika. (eds.) (2017). Methods and Approaches in Ethnobotany: Concepts, Practices and Prospects. Deep Publications, Delhi.
14. Kapoor, L. D. (2001). *Handbook of Ayurvedic medicinal plants*. Boca Raton, FL: CRC Press.
15. Saroya, A.S. (2017). Ethnobotany. ICAR publication.
16. Sharma, R. (2003). Medicinal Plants of India-An Encyclopaedia. Delhi: Daya Publishing House.
17. Thakur, R. S., H. S. Puri, and Husain, A. (1989). *Major medicinal plants of India*. Central Institute of Medicinal and Aromatic Plants, Lucknow, India.

Semester- IV

Core Course

Paper Code: BOTC-401

Paper Title: Economic Botany and Plant Resource Utilization (Theory)

Credit: 4

Unit I: Origin and Conservation of Cultivated Plants

15 lectures

Origin, Importance and domestication: Origin of Agriculture and ancient economic botany, Vavilov's Centres of Origin and diversity of crop plants, domestication, evaluation, bioprospection, Major plant introductions; Crop domestication and loss of genetic diversity; Germplasm augmentation and conservation: History and importance of germplasm collection; Overview of : Ecogeographical distribution of diversity, General account of : Biotechnology in plant germplasm acquisition, plant tissue culture in disease elimination, in vitro conservation and exchange, cryopreservation, transgenics – exchange and biosafety issues; Green revolution; Importance of ethnobotany in gene pool and germplasm conservation.

Unit II: Botany, Utilization of Plant Wealth (Cereals and Millets, Fruits, Pulses and Legumes, Sources of Sugars and Starches)

15 lectures

Origin, evolution and biosystematics, morphology, and uses of some selected crops: Cereals wheat, rice, maize, sorghum, pearl millet and minor millets. Fruits: Citrus and pineapple (origin, morphology, anatomy and uses). Pulses: Origin, morphology, uses, importance to man and ecosystem of pulses (pigeon pea, chickpea, black gram, greengram, cowpea, soyabean, pea, lentil, horsegram), and legumes (lab-lab bean, ricebean, winged bean, French bean, lima bean, sword bean). Morphology and processing of sugarcane, products and by-products. Morphology, propagation and uses of potato, sweet potato and tapioca.

Unit III: Botany, Utilization of Plant Wealth (Spices, Beverages, Oil Seeds Fats and Essential Oils)

15 lectures

Spices: Listing of important spices (cardamom, cinnamon, tejpat, anise, cumin, tamarind, asafoetida, fenugreek, fennel, coriander), their botanical name, family and part used. Origin, distribution, ecology, botany, cultivation practices, processing of economic plant part, product, main chemical constituents, and economic importance of the major spices, namely turmeric, ginger, capsicum, black pepper, coriander.

Beverages: tea and coffee: History, origin, growing countries, botany, cultivation practices, common diseases and pests, major chemical constituents, processing and quality control of economic product.

Oil seeds and fats: General description, classification, extraction and uses of groundnut, coconut, linseed, soybean, mustard. Essential oils: General description, uses extraction / distillation of essential oil, chemical constituents of major essential oil yielding aromatic plants, namely rose, geranium, lemongrass/citronella, menthol mint, basil, lavender, eucalyptus, clove, camphor and sandal wood.

Unit IV: Botany, Utilization and Processing of Plant Wealth (Aromatic Plants, Drug-yielding and Medicinal Plants, Timber Plants) 15 lectures

Drug-yielding and medicinal plants: fumitories and masticatories: processing, therapeutic uses, and health hazards of habit-forming drugs, botany and cultivation / regulatory practices of such drug yielding plants with special reference to papaver, cannabis and tobacco.

Major medicinal plants : Botany, uses, cultivation and processing of major medicinal plants, namely: ashwagandha, bhuvati, asparagus, ghrita kumari (*Aloe vera*), quinghao (*Artemisia annua*), isabgol, senna, amla (*Phyllanthus*), *Stevia*, sarpagandha (*Rauvolfia*), *Atropa*, *Digitalis*, licorice, ningthoukhongli (*Tinospora*).

Natural Rubber: Pararubber: tapping, processing and uses.

Timber plants and Fibres: General account and botany of the tree, wood structure and quality characteristics, and timber processing with special reference to *Dipterocarpus*, teak and pine. General account of the fiber yielding plants, classification based on the origin of fibers, extraction, processing, morphology and uses of fibers, with special reference to cotton, sunhemp, flax.

Pharmacognosy: Aims and objectives, definition, preparation of drugs for commercial market.

Core Course

Paper Code: BOTC 402(P)

Paper Title: Economic Botany and Plant Resource Utilization (Practical)

Credit: 2

1. Cereals: Wheat (habit sketch, L. S/T.S. grain, starch grains, micro-chemical tests) Rice (habit sketch, study of paddy and grain, starch grains, micro-chemical tests).
2. Legumes: Soybean, Groundnut, (habit, fruit, seed structure, micro-chemical tests).
3. Sources of sugars and starches: Sugarcane (habit sketch; cane juice- micro-chemical tests), Potato (habit sketch, tuber morphology, T.S. tuber to show localization of starch grains, w.m. starch grains, micro-chemical tests).
4. Spices: Black pepper, Fennel, *Curcuma* and Clove (habit and sections).
5. Beverages: Tea (plant specimen, tea leaves), Coffee (plant specimen, beans).
6. Sources of oils and fats: Coconut- T.S. nut, Mustard–plant specimen, seeds; tests for fats in crushed seeds.
7. Essential oil-yielding plants: Habit sketch of *Rosa* and *Cymbopogon* spp., Mint, Basil, Eucalyptus (specimens/photographs).
8. Rubber: specimen, photograph/model of tapping, samples of rubber products.
9. Drug-yielding plants: Specimens of *Artemisia*, *Phyllanthus*, *Papaver* and *Cannabis*.
10. Tobacco: specimen and products of Tobacco.
11. Woods: *Tectona*, *Pinus*: Specimen, Section of young stem.

Suggested Readings

1. Chrispeels, M.J. and Sadava, D.E. 1994. Plants, Genes and Agriculture. Jones & Bartlett Publishers.
2. Kochhar, S.L. 2012. Economic Botany in Tropics. New Delhi, India: MacMillan & Co.

3. Lim, T.K. 2012. Edible Medicinal and Non-Medicinal Plants. Springer Dordrecht Heidelberg London New York
4. Sambamurty, AVSS and Subrahmanyam, N.S. 2008. A Textbook of Modern Economic Botany. 1st Edition, Paperback . CBS Publishers & Distributors Pvt.Ltd.; 1st edition
5. Wickens, G.E. 2001. Economic Botany: Principles & Practices. Kluwer Academic Publishers, The Netherlands.

Core Course

Paper Code: BOTC-403

Paper Title: Molecular Biology (Theory)

Credit: 4

Unit I

12 Lectures

Historical perspective; Experiments that established nucleic acids (DNA & RNA) as the carrier of genetic information: Griffith's, Hershey & Chase, Avery, McLeod & McCarty and Fraenkel-Conrat 's experiment .

Unit II

15 Lectures

DNA Structure: Miescher to Watson and Crick- a historic perspective. DNA structure, salient features of double helix; Types of DNA: A, B & Z conformations. Genome complexity: Concept of C-value paradox, denaturation and renaturation, *Cot* curves; Organization of DNA- in Prokaryotes, Viruses & Eukaryotes. Organelle DNA -- mitochondria and chloroplast DNA; Chromatin structure- Nucleosome, Euchromatin, Heterochromatin Constitutive and Facultative heterochromatin. RNA: types of RNA molecules, structure and function of mRNA, tRNA and rRNA

Unit III

18 Lectures

Key experiments establishing-The Central Dogma, Genetic code (salient features & experiments that deciphered the correlation between mRNA codon and amino acid). Mechanism - initiation, elongation and termination, Kornberg's discovery; Enzymes and other proteins involved in DNA replication; General principles – bidirectional, semiconservative and semi discontinuous replication (Replisome), RNA priming (primase & Primosome); Various modes of DNA replication, including rolling circle, θ (theta) mode of replication, replication of linear ds-DNA. Replication of the 5' end of linear chromosome (end replication problem & Telomerase).

Unit IV

15 Lectures

Transcription in prokaryotes and eukaryotes; Understanding the steps in process of transcription: Initiation, Elongation and Termination. Enzymes and factors involved in transcription. Translation in prokaryotes and eukaryotes; Understand the steps in process of translation - Initiation, Elongation and Termination. Enzymes and factors involved in translation. Ribosome structure and assembly (in prokaryotes and eukaryotes); charging of tRNA, aminoacyl tRNA synthetases; Fidelity of translation; Inhibitors of protein synthesis; post-translational modifications of proteins.

Paper Code: BOTC-404(P)

Paper Title: Molecular Biology (Practical)

Credit: 2

1. Preparation of LB medium and raising *E. coli*
2. DNA isolation from cauliflower heads
3. Quantification of unknown DNA by diphenylamine reagent.
4. Study of experiments establishing nucleic acid as genetic material (Avery et al, Griffith's, Hershey & Chase's and Fraenkel & Conrat's experiments) through photographs
5. Numerical based on DNA re-association kinetics (melting profiles and *Cot* curves)
6. Study of DNA replication through photographs: Modes of replication - Rolling circle, Theta and semi-discontinuous; Semiconservative model of replication (Messelson and Stahl's experiment); Telomerase assisted end-replication of linear DNA

Suggested readings

1. Klug, W.S., Cummings, M.R., Spencer, C.A. 2009. Concepts of Genetics. Benjamin Cummings. U.S.A. 9th edition.
2. Russell, P. J. 2010. iGenetics- A Molecular Approach. Benjamin Cummings, U.S.A. 3rd edition.
3. Snustad, D.P. and Simmons, M.J. 2010. Principles of Genetics. John Wiley and Sons Inc.,U.S.A. 5th edition
4. Watson J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M., Losick, R. 2007. Molecular Biology of the Gene, Pearson Benjamin Cummings, CSHL Press, New York, U.S.A. 6th edition. 7th edition

Core Course

Paper Code: BOTC – 405

Paper Title: Plant Morphology and Anatomy (Theory)

Credit: 4

Unit I: Morphology of vegetative organs

15 lectures

Importance of plant morphology, Parts of an angiospermic. Morphology and characteristic of root, Types of root system, Regions of the root, Modifications of root, Morphology and characteristic of stem, Forms of stem, Bud and its modifications, Habit of the plant: parasitic, mycoheterotropic and epiphytic plants, Modifications of stem, Types of branching, Functions of stem Morphology of leaf, Parts of a leaf, types of leaves, types of stipules and their modifications, leaf blade w.r.t. apex, margin, and shape, Venation, Simple and compound leaves, Modifications of leaves, Phyllotaxy Functions of leaves,

Unit II: Morphology of reproductive organs 15 lectures

inflorescence: Definition, Classification of inflorescences - Racemose and its types and Cymose and its types, Flower as a modified shoot, structure of flower, types of flower, thalamus, bracts, Symmetry of the flower, Calyx and its modifications, Forms of corolla Androecium: Parts of stamen, cohesion of stamens, adhesion of stamens, length of stamens; Gynoecium: Parts of carpel, simple and

compound gynoecium, cohesion of carpels, placentation and its types; Fruit: Definition, Parts of fruit, Classification of fruits, Dispersal of seeds and fruits; Seed: Definition, Parts of dicotyledonous and monocotyledonous seeds, Seed germination and its types.

Unit III: Internal organization and primary plant body **15 lectures**

Tissues: Definition, classification of tissues – Meristem, Simple and complex tissues, Pits and plasmodesmata; Wall ingrowths and transfer cells; Ergastic substances. Hydathodes, cavities, lithocysts and laticifers. Evolution of concept of organization of shoot apex (Apical cell theory, Histogen theory, Tunica Corpus theory, continuing meristematic residue, cytohistological zonation); Types of vascular bundles; Structure of dicot and monocot stem. Structure of dicot and monocot leaf, Kranz anatomy. Organization of root apex (Apical cell theory, Histogen theory, KorperKappe theory); Quiescent centre; Structure of dicot and monocot root; Mechanical tissues and their distribution. Root- stem Transition.

Unit IV: Secondary growth and protective and adaptive system **15 lectures** Structure, function and seasonal activity of cambium; Secondary growth in root and stem. Anomalous secondary growth; Types of rays and axial parenchyma; Cyclic aspects and reaction wood; Sapwood and heartwood; Hard and Soft wood Ring and diffuse porous wood; Early and late wood, tyloses; Dendrochronology. Development and composition of periderm, rhytidome and lenticels. Epidermal tissue system: cuticle, trichomes (uni-and multicellular, glandular and non-glandular, two examples of each); stomata (classification); Adcrustation and incrustation; Anatomical adaptations of xerophytes and hydrophytes. Applications of anatomy in systematics, forensics and Pharmacognosy

Paper Code: BOTC – 406(P)

Paper Title: Plant Morphology and Anatomy (Practical)

Credit: 2

1. Study of anatomical details through permanent slides/temporary stain mounts/macerations/museum specimens with the help of suitable examples or experimentally
2. Study of stomata through peel method and replica method.
3. Simple microtomy – hand sections and / or using microtome- handheld or rotary microtome
4. Staining techniques
5. Apical meristem of root, shoot and vascular cambium (Permanent slides)
6. Distribution and types of parenchyma, collenchyma and sclerenchyma (Permanent slides)
7. Xylem: Tracheary elements-tracheids, vessel elements; thickenings; perforation plates; xylem fibres. (Permanent slides)
8. Wood: ring porous; diffuse porous; tyloses; heart- and sapwood. (Permanent slides)
9. Phloem: Sieve tubes-sieve plates; companion cells; phloem fibres. (Permanent slides)
10. Epidermal system: cell types, stomata types; trichomes: non-glandular and glandular.
11. Root: monocot, dicot, secondary growth.

12. Stem: monocot, dicot - primary and secondary growth; anomalous secondary growth in Achyranthes, Bougainvillea, Nyctanthes and Dracaena; periderm; lenticels.
13. Leaf: isobilateral, dorsiventral, C4 leaves (Kranz anatomy).
14. Adaptive Anatomy: xerophytes, hydrophytes.
15. Secretory tissues: cavities, lithocysts and laticifers.
16. Study of different types of modifications of Stem, Root and Leaf.
17. Study of different types of fruit.
18. Study of different types of inflorescence

Recommended Books

1. Bhattacharya H., Ghosh. 2017. A Textbook of Botany, Vol I – IV, NCBA, Kolkata 2.
- Dickison, W.C. 2000. Integrative Plant Anatomy. Harcourt Academic Press, USA.
3. Evert, R.F. 2006. Esau's Plant Anatomy: Meristems, Cells, and Tissues of the Plant Body: Their Structure, Function and Development. John Wiley and Sons, Inc Fahn, A. 1974. Plant Anatomy. Pergmon Press, USA.
4. Mauseth, J.D. 1988. Plant Anatomy. The Benjammin/Cummings Publisher, USA.
5. Mitra, J.N. D. Mitra, D., S.K. Chowdhuri, S.K. 2017. Studies in Botany Vol. 1 and 2, Moulik Library, Kolkata.
6. Pandey, B.P. 2001. Plant Anatomy, S. Chand Publishing, New Delhi 7. Vasistha, P.C. 2000. Plant Anatomy, Pradeep Publications, Jalandhar.

Generic Elective Course

Paper Code: BOTG-401

Paper Title: Seed Technology (Theory)

Credit: 4

Unit I

15 lectures

Theory of seed development and morphology, Principles of seed production in agricultural crops, seed production in vegetables, fruits, flowers, forage and fodder crops. Seed dormancy: possible reasons and methods of breaking of dormancy.

Unit II

15 lectures

Concept of seed processing, diversity in seed storage and viability issues, Methods of testing of seed viability. Behaviour of seed germination and concept of speed of germination/seed vigour, design of experiments for evaluation of seed related traits.

Unit III

18 lectures

Methods used for seed testing, ISTA (International Seed Testing Association) Rules procedure of seed certification and quality control, basis outlines of seed pathology and seed entomology.

Unit IV

12 lectures

Economics of seed production and marketing, seed production in medicinal and aromatic plants, Concept of hybrid seed and production

Paper Code: BOTG-402(P)

Paper Title: Seed Technology (Practical)

Credit: 2

1. Seed viability testing
2. Seed moisture analysis
3. Seed priming for breaking seed dormancy
4. Seed constituents analysis
5. Seed germination studies ; monocots , dicots
6. Synthetic seed development
7. Visit to seed testing laboratories

Suggested readings

1. Agrawal, P. K., (2010).Principles of Seed Technology. Indian Council of Agricultural Research, New Delhi.
2. Agrawal, R.L. (2015). Seed Technology. Oxford & Ibh Publishing Co Pvt Ltd.
3. Basra, A. (2006). Handbook of Seed Science and Technology. CRC Press.
4. Khare, D. and Bhale, M. S. (2014). Seed Technology 2nd Revision, Jain Book Agency.
5. International Rules for Seed Testing, 2018 (Free online)

Generic Elective Course

Paper Code: BOTG-403

Paper Title: Food Science (Theory)

Credit: 4

Unit I

12 lectures

Food Chemistry: Sources and Classification of Carbohydrates, proteins, lipids and Minerals .Participation in metabolic pathways.

Unit II 15 lectures Food Microbiology: Sources of microorganisms in food, Principles of food spoilage, food borne illness. Food Processing: Dairy industry, Fruit processing, meat industry, processing and preservation. Beverages technology: Coffee, beer and wine etc.

Unit III

18 lectures

Nutrition, Nutraceuticals and functional foods: Classification and characteristics of functional foods. Processing technology and incorporation. Food Toxins: Natural, microbial and chemical toxins in food processing. Food Packaging: Aseptic and Packaging of specific foods, fruits, vegetables, dairy products, cereals snacks etc.

Unit IV

15 lectures

Food laws and quality control: Food safety and standard act (2006) and other Indian and International standards. Food Biotechnology: Biotechnology in food industry, production of

biocolours, flavours, vitamins, biopreservatives, antibiotics and industrial alcohol.
Genetically modified foods.

Paper Title: Food Science (Practical)

Paper Code: BOTG-404(P)

Credit: 2

1. Non-thermal and thermal methods of food preservations
2. Meat and Poultry processing technology
3. Post-harvest technology at small scale
4. Food drying
5. Fermentation technology
6. Project work
7. Industrial visit
8. Fruit and vegetables processing
9. Determination of
 - a. Moisture of food samples
 - b. Protein
 - c. Ash
 - d. Fat
 - e. Sugars- reducing and non-reducing

Suggested readings

1. Damodaran, S., Parkin, K.L. and Owen, R. (2008). Fennema's Food Chemistry . CRC Press.
2. Chopra, H. K. and Penesor, P.S. (2010). Food Chemistry. Narosa Publishing (2010).
3. Pelczar, M.J. and Michael, J. (1999). Microbiology. McGraw-Hill.
4. Jay, J.M. (2005). Modern Food Microbiology (7th edition) by Golden Food Science Text Series.
5. Frazier, W.C. and Weshoff, D.C. (2015). Food Microbiology (5th edition) McGraw- Hill.
6. Kumari, S. (2012). Basics of Food Biochemistry and Microbiology. Koros Press.
7. Whitaker. J.R. (2016). Handbook of Food Enzymology. CRC press
8. Shewfelt, R.L.(2013). Introducing Food Science. CRC Press.
9. Smith, J.S. and Hui, Y.H.(2014) Food Processing. Wiley.
10. Varzakas, T. and Tzia, C. (2016). Handbook of Food Processing. CRC Press.
11. Potter, N. N.(2007). Food Science. CBS Publishers.

Generic Elective Course

Paper Code: BOTG-405

Paper Title: Industrial Microbiology (Theory)

Credit: 4

Unit I

18 Lectures

Scope of microbes in industry and environment; institutes of microbial research. Solid-state and liquid-state (stationary and submerged) fermentations; Batch and continuous Fermentations; Components of a typical bioreactor, Types of bioreactors: laboratory, pilotscale and production fermenters; Constantly stirred tank fermenter, tower fermenter, fixed bed and fluidized bed bioreactors and air-lift fermenter.

Unit II

15 Lectures

Microorganisms involved, microorganisms generally regarded as safe (GRAS), media, fermentation conditions, downstream processing and uses; Filtration, centrifugation, cell disruption, solvent extraction, precipitation and ultrafiltration, lyophilization, spray drying; production of industrially important products: enzyme (amylase); organic acid (citric acid); alcohol (ethanol); antibiotic (penicillin)

Unit III

12 Lectures

Production of industrially important products: enzyme (amylase); organic acid (citric acid); alcohol (ethanol); antibiotic (penicillin). Microbial fermentations, antibiotics, vaccines. Microbes in bioremediation

Unit IV

15 Lectures

Overview of enzymes used for industrial applications, Methods of immobilization, advantages and applications of immobilization, large scale applications of immobilized enzymes: glucose isomerase and penicillin acylase

Generic Elective Course

Paper Code: BOTG-406(P)

Paper Title: Industrial Microbiology (Practical)

Credit: 2

1. Principles and functioning of instruments in microbiology laboratory (autoclave, laminar air flow, incubators, types of fermenters)
2. Preparation of different culture media (Nutrient medium/ Luria Bertani medium/Potato dextrose medium/Czapek-Dox medium)
3. Hydrolysis of casein / starch by microorganisms
4. Alcohol production by yeast using sugar/ jaggery
5. Serial dilution method for isolation of microorganisms from water and soil and study of aeromicroflora.
6. A visit to any educational institute/ industry to see an industrial fermenter, and other downstream processing operations and a report to be submitted.

Suggested readings

1. Pelzar, M.J. Jr., Chan E.C. S., Krieg, N.R. (2010). *Microbiology: An Application based approach*. New Delhi, Delhi: McGraw Hill Education Pvt. Ltd., Delhi.

2. Tortora, G.J., Funke, B.R., Case. C.L. (2007). *Microbiology*. San Francisco, SF: Pearson Benjamin Cummings,. 9th edition
3. Stanbury, P.F., Whitaker, A., Hall, S.J. (2016) *Principles of Fermentation Technology*. Amsterdam, NDL:Elsevier Publication
4. Patel, A.H. (2008) *Industrial Microbiology*, Bangalore, India: McMillan India Limited
5. Mohapatra. P.K. (2008). *Textbook of Environmental Microbiology* New Delhi, Delhi, I.K. International Publishing House Pvt.Ltd.
6. Bertrand, Jean-Claude, Caumette, P. , Lebaron, P, Matheron, R., Normand, P., SimeNgando, T. (2015) *Environmental Microbiology: Fundamentals and Applications*. Amsterdam, Netherlands, Springer
7. Joe, S., Sukesh (2010). *Industrial Microbiology*. New Delhi, Delhi: S.Chand & Company Pvt. Ltd.,
8. Casida, J.R. (2016). *Industrial Microbiology*. New, Delhi, Delhi, New Age International Publishers
9. Atlas, Bartha. (1997). *Microbial Ecology: Fundamentals and Applications*. San Fransisco, SF. Pearson
10. Sharma, P.D. (2005)., *Environmental Microbiology*. Meerut, UP: Alpha Science International, Ltd

Semester V

Core Course

Paper Code: BOTC - 501

Paper Title: Reproductive Biology of Angiosperms (Theory)

Credit: 4

Unit I: Historical Perspective and Reproduction in Plants **6 lectures**

History (contributions of G.B. Amici, W. Hofmeister E. Strasburger, S.G. Nawaschin, P. Maheshwari, B.M. Johri, W.A. Jensen, J. Heslop-Harrison) and scope of reproductive biology; Types of reproduction and regeneration in plants: Sexual, asexual / vegetative reproduction.

Unit II: Male and Female Gametophyte Development **18 lectures**

Anther and pollen biology: Anther wall: Structure and functions, micro-sporogenesis, Microgametogenesis; Pollen wall structure, MGU (male germ unit), NPC system (no details but table to be included); Palynology and scope (a brief account); Pollen wall proteins; Pollen viability. Unique features: Pseudomonads, polyads, massulae, pollinia. Ovule: Types of ovules; Special structures—endothelium, obturator, aril, caruncle and hypostase; Female gametophyte—mega-sporogenesis (monosporic, bisporic and tetrasporic) and megagametogenesis (details of Polygonum type); Organization and ultrastructure of mature embryo sac.

Unit III: Pollination, Fertilization and Self-Incompatibility **18 lectures**

Pollination types and significance; adaptations; structure of stigma and style; path of pollen tube in pistil; double fertilization. Self-incompatibility: Basic concepts (interspecific, intraspecific, homomorphic, heteromorphic, GSI and SSI); Methods to overcome selfincompatibility: mixed pollination, bud pollination, stub pollination; Intra-ovarian and in vitro pollination; Modification of stigma surface, parasexual hybridization, Cybrids, In Vitro Fertilization (IVF)

Unit IV: Embryo, Endosperm and Seed, Polyembryony and Apomixes **18 lectures**

Structure and types of embryo; General pattern of development of dicot and monocot embryo; Suspensor: structure and functions; Endosperm: types, structure and development; Embryo-endosperm relationship; Nutrition of embryo; Seed structure, importance and dispersal mechanisms. (Adaptations – Autochory, Anemochory, Hydrochory, Zoochory with 2 examples each). Polyembryony and apomixes: Introduction; Classification; Causes and applications.

Paper Code: BOTC – 502(P)

Paper Title: Reproductive Biology of Angiosperms (Practical)

Credit: 2

1. Anther: Wall structure; Tapetum (amoeboid and glandular); MMC, spore tetrads, uninucleate, bi-celled and dehisced anther stages through slides/micrographs,

2. Pollen grains: Fresh and acetolyzed pollen grains showing ornamentation and aperture, pseudomonads, polyads, pollinia (slides/photographs, fresh material), ultrastructure of pollen wall (micrograph); Pollen viability: Tetrazolium test. Demonstration of pollen germination using hanging drop method.
3. Ovule: Types-anatropous, orthotropous, amphitropous/ campylotropous, circinotropous, unitegmic, bitegmic; Tenuinucellate and crassinucellate; Special structures: Endothelium, obturator, hypostase, caruncle and aril through permanent slides/ specimens/ photographs.
4. Female gametophyte through permanent slides/ photographs: Types, ultrastructure of mature embryo sac.
5. Intra-ovarian pollination; Test tube pollination through photographs.
6. Pollination and Seed dispersal mechanisms (adaptations through photographs / specimens)
7. Endosperm: Dissections of developing seeds for endosperm with free-nuclear haustoria. Embryogenesis: Study of development of dicot embryo through permanent slides and Study of suspensor through electron micrographs.
8. Embryogenesis: Study of development of dicot embryo through permanent slides and Study of suspensor through electron micrographs.
9. Dissection of developing seeds for embryos at various developmental stages

Recommended Books:

1. Bhojwani, S.S., Bhatnagar, S.P. Dantu P. K. 2015. The Embryology of Angiosperms, 6th Edition, Vikas Publishing House, New Delhi, Delhi:
2. Johri, B.M. 1984. Embryology of Angiosperms, Springer-Verlag, Netherlands
3. Pandey, A.K. 1997. Introduction to Embryology of Angiosperms. CBS Publishers & Distributors, New Delhi.
4. Raghavan, V. 2000. Developmental Biology of Flowering plants, Springer, Netherlands
- Shivanna, K.R. 2003. Pollen Biology and Biotechnology. Oxford and IBH Publishing Co. Pvt. Ltd. Delhi.
5. Shivanna, K.R. 2003. Pollen Biology and Biotechnology. New Delhi, Delhi: Oxford and IBH Publishing Co. Pvt. Ltd.

Core Course

Paper Code: BOTC – 503

Core Course: Plant Physiology (Theory)

Credit: 4

Unit I: Plant water relationship

15 lectures

Diffusion, Osmosis, Imbibition and Plasmolysis; Water potential and its components, water absorption by roots, aquaporins, pathway of water movement--symplast, apoplast, transmembrane pathways, root pressure, guttation, Ascent of sap – Vital and Physical theories (cohesion-tension theory), Transpiration - Types and factors affecting transpiration, antitranspirants, mechanism of stomatal opening - starch-sugar hypothesis, proton transport theory, blue light stimulated response.

Unit II: Mineral nutrition and uptake **15 lectures**

Soil - components, types and source of plant nutrients, Essential and beneficial elements, macro- and micronutrients, methods of study and use of nutrient solutions (ash analysis, hydroponics, aeroponics), criteria for essentiality, mineral deficiency symptoms, roles of essential elements, chelating agents (including phytosiderophores). Transport of ions across cell membrane--passive absorption: simple (Fick's law) and facilitated diffusion (carrier and channel proteins), active absorption, uniport, co-transport (symport, antiport), role of mycorrhizae (in brief). Experimental evidence in support of phloem as the site of sugar translocation, source-sink relationship, Pressure-Flow Model, phloem loading and unloading

Unit III: Plant growth regulators **15 lectures**

A brief description on Growth, development and differentiation; Discovery, chemical nature (basic structure, precursor), bioassay, physiological roles of Auxins, Gibberellins, Cytokinins, Abscisic Acid, Ethylene; Applications of Phytohormones in agriculture and horticulture; mechanism of action of auxins; Roles of Polyamines, Brassinosteroids, and Jasmonic acid (brief introduction); Senescence and its types, Introduction of Programmed cell death(PCD).

Unit IV: Physiology of flowering and photomorphogenesis **15 lectures**

Photoperiodism – Discovery and definition, SDP, LDP and DNP, Critical photoperiod, flowering stimulus, concept of florigen, CO-FT Model for long-distance transport of flowering stimulus, ABC model of flowering (in brief), vernalization, seed dormancy (causes and methods to overcome dormancy); Discovery, chemical nature and photo reversibility of Phytochrome, role of phytochrome in flowering and tropisms, low energy responses (LER) and high irradiance responses (HIR), mode of action. Circadian rhythms in plants (exogenous factors and physiological mechanism). Tropic and nastic movements.

Paper Code: BOTC – 504(P)

Core Course: Plant Physiology (Practical)

Credit: 2

1. Determination of osmotic potential of plant cell sap by plasmolytic method.
2. Determination of water potential of given tissue (potato tuber) by weight method.
3. Determination of water potential of given tissue (potato tuber) by falling drop method.
4. Study of the effect of light on the rate of transpiration in excised twig/ leaf.
5. Calculation of stomatal index and stomatal frequency from the two surfaces of leaves of a mesophyte and a xerophyte.
6. To calculate the area of an open stoma and percentage of leaf area open through stomata in a mesophyte and a xerophyte (any one surface).
7. To compare the rate of transpiration from both the surfaces of a dorsiventral leaf.
8. To determine transpiration – Absorption ratio in a plant.
9. Analysis of plant ash for presence of mineral elements (Ca, Mg, Fe, Cu, P, S, Mo)
10. To study the phenomenon of seed germination (effect of light and darkness).
11. To study the induction of amylase activity in germinating barley grains.

Recommended Books

1. Bajracharya, D. 1999. Experiments in Plant Physiology: A Laboratory Manual. New Delhi, Delhi: Narosa Publishing House.
2. Bhatla, S.C., Lal, M.A. 2018. Plant Physiology, Development and Metabolism. Singapore: Springer Nature, Singapore Pvt. Ltd.
3. Buchanan, B.B. and Gruissem, W. 2015. Biochemistry and molecular biology of plants. Willy Blackwell ASPB USA.
4. Hopkins, W. G., Huner, N. P. A.(2009. Introduction to Plant Physiology, 4th edition. New Delhi, Delhi: Wiley India Pvt. Ltd.
5. Jain, V.K 2017. Fundamentals of Plant Physiology, S Chand Publishing, New Delhi Kochhar, S.L., Gujral, S.K. 2017. Plant Physiology: Theory and Applications. New Delhi, Delhi: Foundation Books, Cambridge University Press India Pvt, Ltd.
6. Mukherji, S., Ghosh, A.K.nd A. K., 2006. Plant Physiology, New Central Book Agency (P) Limited, Kolkata Pandey, S.N. Sinha, B.K. 2006. Plant Physiology, Vikas Publishing House Pvt Ltd. New Delhi.
7. Srivastava, H.N. 2005. Plant Physiology, Predeep Publications, Jalandhar.
8. Taiz, L., Zeiger, E., Moller, I. M., Murphy, A. 2018. Plant Physiology and Development, International 6th edition. New York, NY: Oxford University Press, Sinauer Associates.

Discipline Specific Elective Course

Paper Code: BOTD - 505

Paper Title: Stress Physiology (Theory)

Credit: 4

Unit I: Concept of Plant Stress and Strain

12 lectures

Stress and Strain terminology; Abiotic and Biotic Stress; Stress and stress factors, Resistance Mechanisms; Tolerance, Acclimation and avoidance.

Unit II: Abiotic and Biotic Stress Factors

18 lectures

Water stress; Salinity stress, High light stress; UV and Ionizing radiation injury: Temperature stress; mechanism of tolerance, Hypersensitive reaction; Pathogenesis– related (PR) proteins; Systemic acquired resistance; Mediation of insect and disease resistance by jasmonates. Signal transduction and various mechanisms of acquiring resistance. Pyrethroids, isoprenoids and allelopathy.

Unit III: Stress Sensing Mechanisms in Plants

14 lectures

Signalling: Hormonal, Calcium modulation, Phospholipid signaling.

Unit IV: Developmental and Physiological Mechanisms that Protect Plants Against Environmental Stress

16 lectures

Adaptation in plants; Changes in root:shoot ratio; Aerenchyma development; Osmotic adjustment; Compatible solute production.

Reactive oxygen species: Production and scavenging mechanisms of ROS.

Paper Code: BOTD – 506(P)

Paper Title: Stress Physiology (Practical)

Credit: 2

1. Determination of osmotic potential and RWC in plant tissue.
2. Effect of light/Temperature on pigment oxidation.
3. Determination of oxidative damage in tissue using TBARS method.
4. Morphological and anatomical variations in plants under stress (such as number of stomata/chl-a/b ratio and anatomical variations).
5. Stress induced organic solute Proline as a physiological marker of stress.
6. Quantitative estimation of peroxidase activity in the seedlings in the absence and presence of salt stress.
7. Superoxide activity in seedlings in the absence and presence of salt stress.
8. Zymographic analysis of peroxidase, superoxide dismutase, and catalase.ive estimation and zymographic analysis of glutathione reductase.
9. More Practical may be added depending on the local habitats and available facilities

Suggested Readings

1. Hopkins, W.G. and Huner, A. (2008). Introduction to Plant Physiology. 4th edition. John Wiley and Sons., U.S.A.
2. Taiz, L., Zeiger, E., MØller, I.M. and Murphy, A. (2015). Plant Physiology and Development. 6th edition. Sinauer Associates Inc., USA.
3. Singh D.P. (2003). Stress Physiology. New Age

Discipline Specific Elective Course

Paper Code: BOTD - 507

Paper Title: Plant Breeding (Theory)

Credit: 4

Unit I: Introduction to Plant Breeding

10 lectures

Introduction and objectives. Breeding systems: modes of reproduction in crop plants. Selfincompatibility, male sterility and apomixis. Important achievements and undesirable consequences of plant breeding.

Unit II: Methods of Crop Improvement

20 lectures

Introduction: Centres of origin and domestication of crop plants, plant genetic resources; Acclimatization; Selection methods: For self-pollinated, cross pollinated and vegetatively propagated plants; Hybridization: For self, cross and vegetatively propagated plants – Procedure, advantages and limitations.

Unit III: Quantitative Inheritance 10 lectures Concept, mechanism, Monogenicvs polygenic Inheritance, QTL and QTL Mapping, Case studies in inheritance of Kernel colour in wheat, Fruit quality in tomato.

Unit IV: Inbreeding Depression and Heterosis 10 lectures
History, genetic basis of inbreeding depression and heterosis; Applications.

Crop Improvement and Breeding 10 lectures
Role of mutations; Polyploidy; Distant hybridization, Molecular Breeding, Marker assisted selection, Role of biotechnology in crop improvement.

Paper Code: BOTD – 508(P)

Paper Title: Plant Breeding (Practical)

Credit: 2

1. Introduction to field /controlled pollinations in field and laboratory (temporal details of anthesis, anther dehiscence, stigma receptivity and pollen viability, emasculation, bagging in tentative species: pea, *Brassica*, chickpea, wheat).
2. Analysis of the breeding system of chosen crop species by calculating Pollen:Ovule Ratio
3. Calculation of Index of self-incompatibility (ISI) and Confirmation of Self Incompatibility.
4. Study of Quantitative and qualitative characters in select crops.
6. Study of Pollinators.
7. Assessment of genetic diversity by using Molecular Markers.

Suggested Readings

1. Acquaah, G. (2007). Principles of Plant Genetics & Breeding. New Jersey, U.S.: Blackwell Publishing.
3. Singh, B.D. (2005). Plant Breeding: Principles and Methods, 7th edition. New Delhi, Delhi: Kalyani Publishers.
2. Chaudhari, H.K. (1984). Elementary Principles of Plant Breeding, 2nd edition. New Delhi, Delhi: Oxford – IBH.

Discipline Specific Elective Course

Paper Code: BOTD - 509

Paper Title: Plant Pathology (Theory)

Credit: 4

Unit-I: Basic Concept of Plant Pathology 15 Lectures

Introduction to the science of phytopathology, its objectives, scope and historical background.

Classification of plant diseases, symptoms, signs, and related terminology. Definitions of terminology - bacteria, fungi, viruses, viroids, phytoplasmas, fastidious vascular bacteria, parasites, pathogens, biotrophs, hemibiotrophs, necrotrophs. Pathogenicity, pathogenesis, virulence, infection, inoculum, invasion, colonization, inoculum potential, symptoms, incubation period.

Unit-II: Plant Pathogens and Crop Diseases**15 Lectures**

Plant pathogens: fungi, bacteria, viruses, phytoplasma, protozoa, algae and parasitic flowering plants their characteristics. Important diseases of rice, maize, wheat, pulses (pea, broad bean, ground nut), sugarcane, vegetables (cabbage, mustard, potato, tomato) and fruit crops (banana, citrus, pineapple). Post-harvest and storage diseases.

Unit-III: Chemical Methods for Disease Control**15 Lectures**

Principles and methods of plant disease management. Chemical methods of disease management: Fungicides- classification, chemical groups of fungicides, inorganic, organic, systemic and contact fungicides, antibiotics. Methods of application of fungicides - seed, soil, foliar spray, post-harvest treatment and root feeding. Botanicals for plant disease control. Integrated plant disease management.

Unit-IV: Alternative Methods for Disease Control**15 Lectures**

Regulatory method, plant quarantine, inspection, rules and regulations. Cultural practices for plant disease management: sanitation, hot weather ploughing, soil amendments, crop rotation, time of sowing, seed rate and plant density, irrigation and drainage. Physical methods of plant disease control. Biological control and biopesticides. Role of biotechnology in plant disease management- tissue culture and transgenic plants.

Paper Code: BOTD – 510(P)**Paper Title: Plant Pathology (Practical)****Credit: 2**

1. Methods of sterilization.
2. Preparation of common culture media for fungi and bacteria.
3. Pure culture technique.
4. Common symptoms of plant diseases caused by fungi, bacteria and viruses.
5. Field identification and laboratory examination of common crop diseases.
6. Familiarization with different groups of fungicides.
7. Preparation of fungicidal spray solutions- methods of application of fungicides - spraying and soil drenching.
8. Seed treatment with systemic and contact fungicides.
9. Preparation and application of botanicals.
10. Familiarization with plant protection equipment.
11. Field visits, survey and collection of disease samples.

Suggested Readings

1. N.G. Ravichandra, 2013. Fundamentals of Plant Pathology. PHI Hall of India, New Delhi
2. R.S. Mehrotra and A. Agarwal, 2003. Plant Pathology. Oxford & IBH, New Delhi.
3. A.V.S.S. Sambhamurthy, 2020. A Textbook of Plant Pathology. Dreamtech Press, New Delhi.
4. R.S. Singh, 2002. Introduction to Principles of Plant Pathology. Oxford & IBH, New Delhi.
5. Alexopoulos, C.J. Mims, C.W. and Blackwell, M. 1996. Introduction to Mycology. Wiley Eastern Ltd., New York.
6. Mandahar, C.L. 1987. Introduction to Plant Viruses. Chand and Co. Pvt. Ltd., New Delhi.
7. Mehrotra, R.S. and Aneja, K.R. 1990. . An Introduction to Mycology. New Age International (P) Ltd., New Delhi.
8. Singh, R.S. 1982. Plant Pathogens - The Fungi. Oxford and IBH Publishing Co., New Delhi.
9. Singh, R.S. 1989. Plant Pathogens - The Prokaryotes. Oxford and IBH Publishing Co., New Delhi.
10. Dhingra and Sinclair 1993. Basic Plant Pathology Methods. CBS, Publishers & Distributors, New Delhi.

11. Agrios, G.N. 2005. Plant Pathology. 5th Edition. Academic press, New York.
12. Y.L. Nene and P.N. Thapliyal, 1993. Fungicides in Plant Disease Control. Oxford & IBH, NewDelhi.
13. J. Palti, 1981. Cultural Practices and Infectious Crop Diseases. Springer-Verlag, New York.
14. R.S. Singh, 1998. Plant Diseases. Oxford & IBH, New Delhi.
15. G. Rangaswami, 1999. Diseases of Crop Plants in India. Prentice Hall of India. New Delhi.

Generic Elective Course

Paper Code: BOTG-501

Paper Title: Environmental Monitoring and Management (Theory)

Credit: 4

UNIT I: Environment Pollution, Assessment and Monitoring **15 lectures**

Ambient Air quality standards, dispersion of air pollutants, air sampling and analysis and control of air pollution. Water quality monitoring: Wastewater characterization. Methods for Measurement of water pollution. Sources, effects, monitoring and controlling measures of soil pollution. Noise standards and limit values. Measurement and analysis of sound, effects of noise on health, measures to control noise pollution. Thermal Pollution: Definition and sources, chemical and biological effects of thermal pollution, effects on water quality. Control of thermal pollution. Sources of marine pollution and its control. Effects of pollutants on human beings, plants, and animals.

UNIT II: Drinking Water Standards Parameters **15 lectures**

Water Characteristics, Indian standard and international standards for drinking water. Physical parameters (Color, taste-odor, Turbidity, suspended solids, Temperature. Chemical parameters (TDS Alkalinity, Hardness, salts, acids and alkalis, chlorides, fluorides, proteins, carbohydrates, organics, fats oil & grease, Hazen units, NTU, BOD, COD, DO, TDS, Trace metals, Heavy metals, tests on quality parameters Plate counts and most probable number (MPN). Sewage and wastewater treatments systems: A. Primary treatment methods B. Secondary treatment methods and C. Tertiary treatment methods.

UNIT III: Wastewater Treatment Technologies **15 lectures**

Aerobic Biological Treatment Processes: Suspended growth and attached growth wastewater treatments. Process fundamentals methods of aeration, design considerations, Operational difficulties. Description, design and operation of aerobic treatment systems: Activated Sludge process- Trickling Filters, RBC. Aerated lagoons, Waste stabilization ponds. Anaerobic Biological Treatment Processes: Anaerobic digestion, Design of anaerobic digesters, Description, design and operation of attached and suspended growth processes: Anaerobic.

UNIT IV: Solid Waste Management **15 lectures**

Municipal Solid Waste Management: Common components in MSW, Chemical and Physical properties of MS, Key Technologies for SWM (collection, handling, transformation, landfills, incinerators, composting), Sources of biomedical wastes, Hazardous biomedical waste. Waste segregation and labeling, Handling, Collection, Storage and transportation management:

Sources, characteristics and categories of hazardous wastes. To know the assessment of Hazardous materials. Hazardous waste collection and transportation of hazardous waste treatment technologies.

Paper Code: BOTG-502(P)

Paper Title: Environmental Monitoring and Management (Practical)

Credit: 2

1. Study of instruments used to measure microclimatic variables: Soil thermometer, maximum and minimum thermometer, anemometer, psychrometer/hygrometer, rain gauge and lux meter.
2. Estimation of hardness and dissolved oxygen, TDS etc. content in water samples.
3. Comparative anatomical studies of leaves from polluted and less polluted areas.
4. Determination of dissolved oxygen of water samples from polluted and unpolluted sources.
5. Making compost from kitchen waste /vermicomposting.
6. Visits to pollution testing centres/stations to understand the pollutants & their emission levels from vehicles.

Suggested Readings

1. Gabriel Bitton. Wastewater Microbiology. 3rd edition, A John Wiley & Sons, INC. Publication. ISBN: 0-471-65071-4.
2. Metcalf and Eddy Inc. (1979) Waste water Engineering treatment, Disposal, Reuse. Tata McGraw Hill Publication. Co. Ltd.
3. Soli J. Arceivala. Wastewater treatment for pollution control. 2nd edition, Tata McGraw Hill Publishing Company Limited. ISBN: 0-07-463002-4.
4. Environmental Pollution and Control, by Dr H.S. Bhatia - Galgotia Publication (P) Ltd
5. Abbasi, S. A, and E. Ramasami. (1999). Biotechnological Methods of Pollution Control, University Press, Hyderabad.
6. Wadhwa Y. (2009). Air Pollution: Causes and Control. Cyber Tech Publications, ND.
7. Sharma, B. K and Kaur, H. (1994). Water Pollution. Krishna PrakashamMandir, Meerut.
8. Wanger K.D, (1998). Environmental Management. W.B. Saunders Co. Philadelphia, USA.
9. Mahajan S.P. (1998). Pollution control in process industries, Tata McGraw Hill, ND.
10. Kreith, F. (Editor in Chief), Handbook of Solid Waste Management. McGraw-Hill, Inc. (1994).
11. Freeman, H. M., Standard Handbook of Hazardous Waste Treatment and Disposal McGraw-Hill, Inc. (1997).

Generic Elective Course

Paper Code: BOTG-503

Paper Title: Global Climate Change (Theory)

Credit: 4

UNIT-I:

15 lectures

Global warming: History and future; Major greenhouse gases; Ozone depletion and UV radiation effects; Ozone layer; Role of ozone in environment; Ozone depleting gases; Green House Effect; future climatic predictions.

UNIT-II: 15 lectures

Temperature profile of the atmosphere; Laps rates; Temperature inversion; Effects of inversion on pollution dispersion; Possible effects and consequences of global warming on weather & climate; Polar ice caps; glaciers and sea level rise; Range of distribution & Phenology of organisms.

UNIT-III: 15 lectures

Factors responsible for global warming and Climate change; Change of Temperature in the environment; role of fossil fuels in global warming and climate change; Impact of human activities on global climate change; Major impacts on forests; Pollution control laws; United Nation Framework Convention on Climate Change, IPCC, Kyoto Protocol, WTO and Environment.

UNIT-IV: 15 lectures Economic and Ecological impacts of climate change; Global and regional strategies to combat global warming and climate change; Action around the world; Climate change mitigation programs in India.

Paper Code: BOTG-504(P)

Paper Title: Global Climate Change (Practical)

Credit: 2

1. Assignments for Review articles on global warming and climate change
2. Presentations on burning issues on global warming and climate change
3. Field visits to realize man-made activities which accelerates global warming and climate change

Suggested readings

1. Gosain, A.K. and Rao,S. 2003. Climate change and India: Vulnerability Assessment and Adaptation. Eds. Shukla,P.R. Universities Press Pvt. Ltd.Hyderabad.
2. Saha,T.K. 2008. Ecology and Environmental Biology. Books and Allied (P) Ltd. Kolkata..
3. Lakshmipathy,M., S.R.Ramanan, R.Sathyanathan and I.S.Sudarsahn. 2009. Proceedings of the National Conference on Effect of climate change and sustainable resource management RM University, Kattankallathur.
4. Rao,M.N, Datar,M.Y. and Reddy,S. 1997. Vermicomposting-A Technological option for solid waste management Ujjain, India.
5. Houghton,J. 2005. Global warming: The Complete Briefing. Cambridge: Cambridge University Press.Cambridge.
6. Claussen E, Cochran VA & Davis DP. 2001. *Climate Change: Science, Strategies and Solutions*. Pew Centre on Global Climate Change, USA.

7. Committee on Abrupt Climate Change. 2002. *Abrupt climate change: Inevitable Surprises*. National Research Council, Ocean Studies Board, National Academics Press, Washington.
8. Koskela J, Buck A &Teissier du Cros E. 2007. *Climate Change and Forest Genetic Diversity: Implications for Sustainable Forest Management in Europe*. 2007. Biodiversity International, Rome, Italy.
9. Anonymous 2006. Report of the National Forest Commission. Govt. of India, New Delhi.
10. Claussen E, Cochran VA & Davis DP. 2001. *Climate Change: Science, Strategies and Solutions*. Pew Centre on Global Climate Change, USA.
11. Committee on Abrupt Climate Change. 2002. *Abrupt climate change: Inevitable Surprises*. National Research Council, Ocean Studies Board, National Academics Press, Washington.

Generic Elective Course

Paper Code: BOTG-505

Paper Title: Environmental Toxicity (Theory)

Credit: 4

UNIT-I:

15 Lectures

Principles of toxicology; Introduction; Classification of toxic agents; Toxic responses; Mechanisms of toxicity; Reaction of the toxicant with target molecules; Distribution and fate of toxic substances.

UNIT-II:

15 lectures

Factors influencing toxicity; Abiotic and biotic factors; Interaction of chemicals; Bioaccumulation and biomagnification; Biochemical effects of Carbon monoxide, Nitrogen oxide, Sulphur dioxide, Ozone & PAN.

UNIT-III:

15 lectures

Risk assessment: Introduction, definition; Hazard identification ; Risk characterization, Doseresponse assessment and Exposure assessment; Ecotoxicological monitoring and tests; Effects of toxic chemicals on human health, animals & plants

UNIT-IV: 15 lectures Production of mycotoxins in general; Fungal toxins; Bacterial toxins; Exo and endo toxins;

Viral toxins; Algal toxins; Teratogen; Carcinogen and mutagens; Chemistry of Toxicology; Pesticides; Heavy metals: Cadmium, Mercury, Lead, Chromium, Zinc; Remedial measures of ecologically toxic materials from different environments.

Paper Code: BOTG-506 (P)

Paper Title: Environmental Toxicity (Practical)

Credit: 2

1. Assignments and review articles on ecotoxicology
2. Deliberations of seminars on ecotoxicants, their toxic effects on ecosystem and organisms and effective remedial measures.
3. Field visit to realize toxicants at waste disposal sites, municipality sewage & drainage, incineration sites and mining sites.

Suggested Readings

1. Trivedy, R. K 1994. Encyclopedia of Environmental Pollution and Control. Enviromedia publications, Karad.
2. Stake, M. Y. Mido, M.S. Sethi, S.A. Iqbal, H. Yasuhisa, S. Taguchi.1997. environmental Toxicology, Discovery publishing house, New Delhi.
3. De, A. K. 1986. Environmental Chemistry, Willey Eastern Limited, New Delhi.
4. Timbrel. 1989. Elements Toxicology, British Council Library.
5. Casseret, L. J and Doull, I. 1982. Toxicology. The basic science of Poisons. Macmillan publishers, New York.

Semester VI

Core Course

Paper Code: BOTC-601

Paper Title: Biostatistics and Bioinformatics (Theory)

Credit: 4

Unit 1: **15 lectures**

Introduction to biostatistics, history and its relevance in biology, Variability in biology, Variable types, Sample and population, sampling units, sampling methods, classification of data, Construction of frequency distribution table and histogram, numerical measures of location and variability, Ecological and statistical population.

Unit 2: **15 lectures**

General introduction to probability, probability distribution, normal distribution. Basic concepts of sampling distribution and standard error; Introduction to test of significance: chi-square and t-test.

Unit 3: **15 lectures**

Basics of bioinformatics and phylogenetic analysis: Scope of bioinformatics; Genomics, Transcriptomics, Proteomics, Metabolomics, Molecular phylogeny, Basics of computational tools, computer aided Drug Design; General introduction to protein sequencing.

Unit 4:15 lectures General introduction to databases: Nucleic acid databases (Genbank, EMBL), Protein databases (Swiss-Prot, PDB), Phylogenetic analysis: similarity, method of alignment (BLAST and FASTA), Phylogenetic tree and analysis, Application of bioinformatics.

Paper Code: BOTC-602(P)

Paper Title: Biostatistics and Bioinformatics (Practical)

Credit: 2

1. Biostatistics:
 - a. Computation of central location of sample data generated from biological experiment,
 - b. Calculation of variability measures,
 - c. Calculation of basic probability related to biological phenomena,
 - d. Calculation of chi-square statistics.
2. Bioinformatics:
 - a. Sequence retrieval (protein and gene) from NCBI.
 - b. Structure download (protein and DNA) from PDB.
 - c. Molecular file formats - FASTA, GenBank, Genpept, GCG, CLUSTAL, Swiss-Prot, FIR.
 - d. Molecular viewer by visualization software.

Suggested readings:

1. Buehler, L.K., Rashidi, H.R. (Ed). 2005. Bioinformatics Basics, CRC Press; 2nd edition
2. Eason, G., Coles, C.W., Gettindy G. 1980. Mathematics and statistics for the biosciences, John Wiley and sons, New York.
3. Freund, J.E. 1994. Modern elementary statistics ,6th edition Prentice Hall,New Jersey.
4. Health, D. 1995. An introduction to experimental design and statistics for biology. UCL Press Ltd, University college, London.
5. Hughes, A.J., Grawoig, D.E. 1971. Statistics ; A foundation for analysis AddisonWesley Educational Publishers Inc
6. Lesk, A.M. 2014. Introduction to bioinformatics .4th edition. Oxford University Press UK,1-440
7. Lohar, P.S. 2015.Bioinformatics, MJP Publishers, Chennai
8. Murthy, C.S.V. 2008. Bioinformatics : Himalaya Publishing House Pvt. Ltd. Mumbai
9. Pansey, V.G., Sukhatme, P.V. 1995. Statistical Methods for Agricultural Workers, ICAR, New Delhi
10. Ramsden, J., 2009, Computational Biology - Bioinformatics: An introduction 2nd edition, Springer,1-271
11. Rastogi, S.C., Mendiratta, N., Rastogi, P. 2013. Bioinformatics-Methods and Applications, PHI Learning Private Limited, Delhi
12. Sharma, V., Munjal, A. and Shanker, A. 2008. A Text Book of Bioinformatics , Rastogi Publications , Meerut
13. Sokal, R.R., Rohls, F.J. 1995. Biometry the principle and practice of statistics in biological research, 3rd edition, W.H. Freeman and company, New York.
14. Xiong, J. 2007. Essential Bioinformatics, Cambridge University Press.

Core Course

Paper Code: BOTC-603

Paper Title: Plant Biotechnology (Theory)

Credit: 4

Unit I:

12 Lectures

Historical perspective of plant tissue culture, Composition of media; Nutrient and hormone requirements (role of vitamins and hormones); Plasticity and Totipotency; Organogenesis; Embryogenesis (somatic and zygotic). Protoplast isolation, culture and fusion; Tissue culture applications (micropropagation, androgenesis, virus elimination, secondary metabolite production, haploids, triploids and cybrids; Cryopreservation; Germplasm Conservation).

Unit II:

15 Lectures

Restriction Endonucleases (History, Types I-IV, biological role and application); Restriction Mapping (Linear and Circular); Cloning Vectors: Prokaryotic (PUC 18 and pUJC19, pBR322. Ti plasmid, BAC); Lambda phage, M13 phagemid, Cosmid, Shuttle vector; Eukaryotic Vectors (YAC and briefly PAC,).

Unit III:**18 Lectures**

Gene Cloning (Recombinant DNA. Bacterial Transformation and selection of recombinant clones, PCR and RT-PCR mediated gene cloning); Gene Construct; construction of genomic and cDNA libraries, screening DNA libraries to obtain gene of interest by genetic selection; complementation, colony hybridization; Probes-oligonucleotide, heterologous, PCR; Methods of gene transfer- *Agrobacterium*-mediated, Direct gene transfer by Electroporation, Microinjection, Microprojectile bombardment: Selection of transgenics— selectable marker and reporter genes (Luciferase, GUS, GFP).DNA fingerprinting by RAPD and RFLP;

Unit IV:**15 Lectures**

Engineering plants to overcome abiotic (drought and salt stress) and biotic stress Pest resistant (Bt-cotton) and herbicide resistant plants (RoundUp Ready soybean); Transgenic crops with improved quality traits (FlavrSavr tomato. Golden rice); Improved horticultural varieties (Moondust carnations); Role of transgenics in bioremediation (Superbug)

Paper Code: BOTC-604(P)**Paper Title: Plant Biotechnology (Practical)****Credit: 2**

1. (a) Preparation of Murashige & Skoog's (MS) medium.
(b) Demonstration of in vitro sterilization and inoculation methods using leaf and nodal explants of tobacco, *Datura*, *Brassica* etc.
2. Study of anther. Embryo and endosperm culture, micro-propagation. Somatic embryogenesis & artificial seeds through photographs.
3. Isolation of protoplasts.
4. Construction of restriction map of circular and linear DNA from the data provided.
5. Study of methods of gene transfer through photographs: *Agrobacterium*-mediated, direct gene transfer by electroporation, microinjection, micro-projectile bombardment.
6. Study of steps of genetic engineering for production of *Bt* cotton, Golden rice, FlavrSavr tomato through photographs.
7. Isolation of plasmid DNA.
8. Restriction digestion and gel electrophoresis of plasmid DNA (demonstration/ photograph).
9. Calculate the percentage similarity between different cultivars of a species using RAPD profile. Construct a dendrogram and interpret results.

Suggested readings

1. Bhojwani, S.S., Bhatnagar, S.P. 2011. *The Embryology of Angiosperms*, 5th edition. New Delhi, Delhi: Vikas Publication House Pvt. Ltd.
2. Bhojwani, S.S., Razdan, M.K., 1996. *Plant Tissue Culture: Theory and Practice*. Amsterdam, Netherlands: Elsevier Science.
3. Glick, B.R., Pasternak, J.J. 2010. *Molecular Biotechnology: Principles and Applications*. Washington, U.S.: ASM Press.

4. Gupta, R., Rajpal, T. 2012. *Concise Notes on Biotechnology*. New Delhi, Delhi: McGraw Hill Publications.
5. Snustad, D.P., Simmons, M.J. 2010. *Principles of Genetics*, 5th edition. Chichester, England: John Wiley and Sons.
6. Stewart, C.N. Jr. 2008. *Plant Biotechnology and Genetics: Principles, Techniques and Applications*. New Jearsey, U.S.: John Wiley & Sons Inc.

Discipline Specific Elective Course

Paper Code: BOTD-605

Paper Title: Microbiology (Theory)

Credit: 4

Unit I:

18 Lectures

Development of microbiology as a discipline. Spontaneous generation vs. biogenesis. Contributions of Anton von Leeuwenhoek, Louis Pasteur, Robert Koch, Joseph Lister, Alexander Fleming Role of microorganisms in fermentation, Germ theory of disease, Development of various microbiological techniques and golden era of microbiology, Development of the field of soil microbiology: Contributions of Martinus W. Beijerinck, Sergei N. Winogradsky, Selman A. Waksman. Establishment of fields of medical microbiology and immunology through the work of Paul Ehrlich, Elie Metchnikoff, Edward Jenner. Binomial Nomenclature, Whittaker's five kingdom and Carl Woese's three kingdom classification systems and their utility.

Unit II:

12 Lectures

Difference between prokaryotic and eukaryotic microorganisms General characteristics of different groups: Acellular microorganisms (Viruses, Viroids, Prions) and Cellular microorganisms (Bacteria, Algae, Fungi and Protozoa) with emphasis on distribution and occurrence, morphology, mode of reproduction and economic importance. Pure culture isolation: Streaking, serial dilution and plating methods; cultivation, maintenance and preservation/stocking of pure cultures;

Unit III:

15 Lectures

Cultivation of anaerobic bacteria, and accessing non-culturable bacteria; Metagenomics and microbiome analysis. Bright Field Microscope, Dark Field Microscope, Phase Contrast Microscope, Fluorescence Microscope, Confocal microscopy, Scanning and Transmission Electron Microscope

Unit IV:

15 Lectures

Nutritional requirements in bacteria and nutritional categories; Culture media: components of media, natural and synthetic media, chemically defined media, complex media, selective, differential, indicator, enriched and enrichment media Physical methods of microbial control: heat, low temperature, high pressure, filtration, desiccation, osmotic pressure, radiation Chemical methods of microbial control: disinfectants, types and mode of action

Paper Code: BOTD-606(P)

Paper Title: Microbiology (Practical)

Credit: 2

2. Microbiology Good Laboratory Practices and Biosafety.
3. To study the principle and applications of important instruments (biological safety cabinets, autoclave, incubator, BOD incubator, hot air oven, light microscope, pH meter) used in the microbiology laboratory.
4. Preparation of culture media for bacterial cultivation.
5. Sterilization of medium using Autoclave and assessment for sterility
6. Sterilization of glassware using Hot Air Oven and assessment for sterility
7. Sterilization of heat sensitive material by membrane filtration and assessment for sterility
8. Demonstration of the presence of microflora in the environment by exposing nutrient agar plates to air.
9. Study of *Rhizopus*, *Penicillium*, *Aspergillus* using temporary mounts

Suggested readings

1. Atlas RM. (1997). Principles of Microbiology. 2nd edition. WM.T.Brown Publishers.
2. Cappucino J and Sherman N. 2010. Microbiology: A Laboratory Manual. 9th edition. Pearson Education Limited
3. Madigan MT, Martinko JM, Dunlap PV and Clark DP. 2014. Brock Biology of Microorganisms. 14th edition. Pearson International Edition
4. Pelczar MJ, Chan ECS and Krieg NR. (1993). Microbiology. 5th edition. McGraw Hill Book Company.
5. Stanier RY, Ingraham JL, Wheelis ML, and Painter PR. (2005). General Microbiology. 5th edition. McMillan.
6. Tortora GJ, Funke BR and Case CL. 2008. Microbiology: An Introduction. 9th edition. Pearson Education
7. Wiley JM, Sherwood LM and Woolverton CJ. 2013. Prescott's Microbiology. 9th Edition. McGraw Hill International.

Discipline Specific Elective Course

Paper code: BOTD-607

Paper Title: Biodiversity Conservation (Theory)

Credit: 4

Unit 1: Plant Diversity and its Scope

15 lectures

Genetic diversity, Species diversity, Plant diversity at the ecosystem level, Agrobiodiversity and cultivated plant taxa, wild taxa. Values and uses of Biodiversity: Ethical and aesthetic values, Precautionary principle, Methodologies for valuation, Uses of plants, Uses of microbes.

Unit 2: Loss of Biodiversity**20 lectures**

Loss of genetic diversity, Loss of species diversity, Loss of ecosystem diversity, Loss of agrobiodiversity, Projected scenario for biodiversity loss,

Management of Plant Biodiversity

Organizations associated with biodiversity management-Methodology for execution-IUCN, UNEP, UNESCO, WWF, NBPGR; Biodiversity legislation and conservations, Biodiversity information management and communication.

Unit 3: Conservation of Biodiversity**10 lectures**

Conservation of genetic diversity, species diversity and ecosystem diversity, *In situ* and *ex situ* conservation, Social approaches to conservation, Biodiversity awareness programmes, Sustainable development.

Unit 4: Role of Plants in Relation to Human Welfare**15 lectures**

a) Importance of forestry their utilization and commercial aspects, b) Avenue trees, c) Ornamental plants of India, d) Alcoholic beverages through ages. Fruits and nuts: Important fruit crops their commercial importance. Wood and its uses.

Paper Code: BOTD-608(P)**Paper Title: Biodiversity Conservation (Practical)****Credit: 2**

1. Mapping species diversity
2. Mapping of crop diversity
3. Visits of plant conservatories
4. Study of wood features
5. Herbarium study of a) Avenue trees, b) Ornamental plants, c) Fruits and nuts, d) Timber plants
6. Procedure of *ex situ* conservation methods
7. Procedure of *in situ* conservation methods

Suggested readings

1. Krishnamurthy, K.V. (2004). *An Advanced Text Book of Biodiversity - Principles and Practices*. New Delhi, Delhi: Oxford and IBH Publications Co. Pvt. Ltd.
2. Samit Ray and Arun K. Ray (2012). *Biodiversity and Biotechnology*. New Central Book Agency (P) Ltd. London. Hyderabad, Delhi, Kolkata, Pune, Guwahati.

Discipline Specific Elective Course**Paper Code: BOTD-609****Paper Title: Post-Harvest Technology (Theory)****Credit: 4****Unit I: Introduction to Post-harvest Technology****12 Lectures**

Introduction to post harvest technology of agricultural produce; Status of Production, Losses,

Need, Scope and Importance. Introduction to various post-harvest operations such as Primary Processing Operation Vs. Secondary Operation, Operations like Harvesting, Handling cleaning, grading, sorting, drying, storage, milling, size reduction, expelling, extraction, blending, heat treatment, separation, material handling (transportation, conveying, elevating), washing; their functions and use in the post-harvest processing.

Unit II: Post-harvest Drying

15 Lectures

Introduction, importance of drying, principles of drying and factors affecting drying, types of drying methods i.e., sun drying & artificial drying by mechanical means – Psychometric Chart, Moisture content representation, equilibrium moisture content, determination of moisture content by direct and indirect methods. Drying Characteristics, Introduction to various grain drying systems - solar drying system, batch drying system, continuous flow drying system. Precautions during drying.

Unit III: Post-harvest Storage

18 Lectures

Introduction, need and importance, general principles of storage. Temperature and moisture changes during storage i.e., influence of moisture content, relative humidity, temperature, fungi etc. on stored product. Fungi, insect and other organism / Infections associated with stored grains. Familiarization with the various types of storage structures. Deep and shallow bins. Traditional and modern storage structures. Management of storage structures. Losses during storage and their control, space requirement of bag storage structure.

Unit IV: Management of Post-harvest Losses

15 Lectures Methods of

Harvesting and Post-harvest losses in fruits and vegetables, Handling of Fruits and Vegetables. Introduction to the storage of fruits and vegetables. Need and importance of storage. Principle of storage of fruits and vegetables. Recommended storage operation conditions for some important fruits and vegetables and their storage life. Post harvest treatment to increase shelf life i.e., freezing, chilling, dehydration, canning, thermal processing. Introduction to Packaging of fruits and vegetables and types of packaging. Concept of modified atmosphere packaging.

Paper Code: BOTD-610(P)

Paper Title: Post-Harvest Technology (Practical)

Credit: 2

1. Determination of physical properties of agricultural materials e.g., size, shape, density and angle of repose of Cereals, Pulses and Oil Seeds Change in Specific Gravity, TSS, Acid of Fruits and Vegetables
2. Determination of moisture content of grains.
3. Study of different types of dryers.
4. Study of domestic grain storage structures.
5. Visit to warehouses, packhouses and cold-storage.
6. Study of different packaging materials.

Suggested readings

1. Post Harvest Technology of Cereal, Pulses, Oil Seeds. A.Chakraverty Oxford & IBH Publication Co.
2. Unit Operation of Agro Processing Engineering. Dr.K.M. Sahay& K.K Singh Vikas Publications.
3. Post Harvest Technology of Fruits & Vegetables Thompson CBS Publishers and Distributors.
4. Post Harvest (Introduction Physiology Handling fruits & Vegetables) Wills R.B.H. Oxford & IBH Publication Co.

Generic Elective Course

Paper Code: BOTG-601

Paper Title: Biodiversity (Theory)

Credit: 4

Unit I: Concept of Biodiversity

13 lectures

What is biodiversity, Genetic diversity, Species diversity, Ecosystem diversity, Alfa beta gamma diversity, Hotspots of biodiversity, India as a mega biodiversity nation, Manipur as a region of biodiversity hotspot, Endangered and endemic species of India and Manipur, Conservation of biodiversity (in-situ and ex-situ); Organizations associated with biodiversity management-IUCN, UNEP, UNESCO, WWF, NBPGR.

Unit II: Microbial Diversity

15 lectures

Tree of Life, 6 Kingdoms of Cavalier-Smith in detail, Evolution of multicellularity. Characteristic features and brief account on classification of viroids, viruses, bacteria and fungi, diversity as illustrated by representative groups of viruses (bacteriophage, mycoviruses, plant viruses and animal viruses), bacteria (Eubacteria and Archaeobacteria) and fungi (Mastigomycotina, Zygomycotina, Ascomycotina, Basidiomycotina and Deuteromycotina).

Unit III: Diversity of Lower Plants

15 lectures

Characteristic features and brief account on classification of algae; diversity of algae as illustrated by the families: Chlorophyceae, Xanthophyceae, Phaeophyceae, Rhodophyceae, and Myxophyceae.

Characteristic features and brief account on classification of bryophytes; diversity of bryophytes as illustrated by the classes: Hepaticopsida, Anthocerotopsida and Bryopsida. Characteristic features and brief account on classification of pteridophytes; diversity of pteridophytes as illustrated by the classes: Psilopsida, Lycopsida, Sphenopsida and Pteropsida.

Unit IV: Diversity of Higher Plants

17 lectures

Characteristic features and brief account on classification of gymnosperms; diversity of gymnosperms as illustrated by the families – Cycadaceae, Ginkgoaceae, Pinaceae, Ephedraceae and Gnetaceae

Characteristic features of angiosperms and dominance of angiosperms on earth; brief account on classification of angiosperms; diversity of flowering plants as illustrated by the families:

Dicotyledons - Brassicaceae, Malvaceae, Rutaceae, Fabaceae, Cucurbitaceae, Apiaceae, Rubiaceae, Asteraceae, Apocynaceae, Solanaceae, Acanthaceae and Euphorbiaceae;
Monocotyledons – Arecaceae, Liliaceae, Musaceae and Poaceae.

Paper code: BOTG-602(P)

Paper Title: Biodiversity (Practical)

Credit: 2

1. EMs/Models of viruses – T-Phage and TMV; Line drawing/Photograph of Lytic and Lysogenic Cycle.
2. Types of Bacteria from temporary/permanent slides/photographs; EM of bacterium, Binary Fission, Conjugation.
3. Gram staining of bacteria.
4. Study of vegetative and reproductive structures of *Nostoc*, *Chlamydomonas*, *Oedogonium*, *Vaucheria*, *Fucus* and *Polysiphonia* through temporary preparations and permanent slides.
5. Study of asexual and sexual stages from temporary mounts and permanent slides of *Rhizopus/Mucor*, *Penicillium/Aspergillus*, *Puccinia/Agaricus*.
6. Study of morphology and anatomy of vegetative and reproductive structures of *Marchantia*, *Anthoceros* and *Funaria* from temporary preparations and permanent slides.
7. Study of morphology and anatomy of vegetative and reproductive structures of *Selaginella*, *Equisetum* and *Pteris* from temporary preparations and permanent slides.
8. Study of morphology and anatomy of vegetative and reproductive structures of *Cycas* and *Pinus*.
9. *Pisum* (Fabaceae), *Coriandrum* (Apiaceae), *Bidens/Acmella* (Asteraceae), *Calotropis* (Apocynaceae), *Phlogacanthus* (Acanthaceae), *Zea/Cynodon* (Poaceae), *Areca* (Arecaceae), *Musa* (Musaceae).
10. Field visit for studying plant and microbial diversity.

Suggested Readings

1. Kumar, H.D. (1999). Introductory Phycology. Affiliated East-West. Press Pvt. Ltd. Delhi.
2. Tortora, G.J., Funke, B.R., Case, C.L. (2010). Microbiology: An Introduction, Pearson Benjamin Cummings, U.S.A.
3. Sethi, I.K. and Walia, S.K. (2011). Text book of Fungi & Their Allies, MacMillan Publishers Pvt. Ltd., Delhi.
4. Alexopoulos, C.J., Mims, C.W., Blackwell, M. (1996). Introductory Mycology, John Wiley and Sons (Asia), Singapore.
5. Raven, P.H., Johnson, G.B., Losos, J.B., Singer, S.R., (2005). Biology. Tata McGraw Hill, Delhi, India.
6. Bhatnagar, S.P. and Moitra, A. (1996). Gymnosperms. New Age International (P) Ltd Publishers, New Delhi, India.

7. Parihar, N.S. (1991). An introduction to Embryophyta. Vol. I. Bryophyta. Central Book Depot, Allahabad.
8. Simpson, M.G. (2006). Plant Systematics. Elsevier Academic Press, San Diego, CA, U.S.A.
9. Singh, G. (2012). Plant Systematics: Theory and Practice. Oxford & IBH Pvt. Ltd., New Delhi. 3rd edition.
10. Vashishta, P.C., Sinha, A.K., Kumar, A., (2010). Pteridophyta, S. Chand. Delhi, India.
11. Sarbhoy, A.K. 2006. Text Book of Mycology, ICAR Publications, New Delhi.
12. Sharma T.A., Dubey, R.C. and Maheshwari, D.K. 1999. A Text Book of Microbiology. S Chand and Co, New Delhi
13. Krishnamurthy, K.V. (2004). *An Advanced Text Book of Biodiversity - Principles and Practices*. New Delhi, Delhi: Oxford and IBH Publications Co. Pvt. Ltd.
14. Samit Ray and Arun K. Ray (2012). Biodiversity and Biotechnology. New Central Book Agency (P) Ltd. London. Hyderabad, Delhi, Kolkata, Pune, Guwahati.

Generic Elective Course

Paper Code: BOTG-603

Paper Title: Plant Taxonomy and Ecology (Theory)

Credit: 4

Unit I: Taxonomic Hierarchy and Botanical Nomenclature **10 lectures**

Ranks, categories and taxonomic groups, Principles and rules of International Code of Nomenclature (ICN), binominal system, typification, author citation, valid publication, rejection of names, principle of priority and its limitations.

Unit II: Classification, Biometrics, Numerical Taxonomy and Cladistics **10 lectures**

Types of classification-artificial, natural and phylogenetic. Bentham and Hooker (up to series), Takhtajan (up to superorder). Characters; variations; OTUs, character weighting and coding; cluster analysis; phenograms.

Unit III: Introduction, Factors, Communities and Ecosystem **20 lectures**

Soil: Origin, formation, composition, soil profile. Water: States of water in the environment, precipitation types. Light and temperature: Variations, Optimal and limiting factors; Shelford law of tolerance. Adaptation of hydrophytes and xerophytes. Characteristics; qualitative and quantitative; Ecotone and edge effect. Succession: processes and types, ecological amplitude. Structure, trophic organisation; energy flow; food chains and food web. Ecological pyramids. Gross and net productivity. Biogeochemical cycles of carbon and nitrogen.

Unit IV: Phytogeography, Introduction to Plant Taxonomy and Taxonomy **20 lectures**

Biogeographical zones; Endemism, Description, Identification, Nomenclature, Classification. Importance of Herbarium, important herbaria and botanical gardens of the world and India; Documentation: Flora, Keys: indented (yolked) and bracketed keys.

Paper Code: BOTG-604(P)

Paper Title: Plant Taxonomy and Ecology (Practical)

Credit: 2

1. Study of vegetative and floral characters of the following families (Description, V.S. flower, section of ovary, floral diagram/s, floral formula/e and systematic position according to Bentham & Hooker's system of classification): Brassicaceae – *Brassica/ Cardamine/ Iberis*; Asteraceae – *Sonchus/Launaea, Vernonia/Ageratum, Eclipta/Tridax*; Solanaceae – *Solanum nigrum, Physalis*; Lamiaceae – *Salvia, Ocimum*; Liliaceae – *Asphodelus / Lilium / Allium*.
2. Mounting of a properly dried and pressed specimen of any wild plants with herbarium label (to be submitted).
3. Study of instruments used to measure microclimatic variables: Soil thermometer, maximum and minimum thermometer, anemometer, psychrometer/hygrometer, rain gauge and lux meter.
4. Determination of pH and analysis of two soil samples for carbonates, chlorides, nitrates, sulphates, organic matter and base deficiency by rapid field test.
5. Comparison of bulk density, porosity and rate of infiltration of water in soil of three habitats.
6. (a) Study of morphological adaptations of hydrophytes and xerophytes (four each).
(b) Study of biotic interactions of the following: Stem parasite (*Cuscuta*), Root parasite (*Orobanche*), Epiphytes.
7. Determination of minimal quadrat size for the study of herbaceous vegetation in the college campus by species area curve method (species to be listed)
8. Quantitative analysis of herbaceous vegetation in the college campus for frequency and comparison with Raunkiaer's frequency distribution law.

Suggested Readings

1. Kormondy, E.J. (1996). Concepts of Ecology. Prentice Hall, U.S.A. 4 edition. Hall, U.S.A.
2. Sharma, P.D. (2010). Ecology and Environment. Rastogi Publications, Meerut, India.
3. Singh, J.S., Singh, S.P. and Gupta, S. (2006). Ecology Environment and Resource Conservation. Anamaya Publications, New Delhi, India.
4. Ambasht R. S. and Ambasht P. K. (1999) Environment and Pollution. C. B. S. Publishers & Distributers, New Delhi.
5. Dash, M. C. (2007). Fundamentals of Ecology. Tata Mc Graw Hill Publishing Company Limited.
6. Verma, P.S. and Agrawal, V. K. (2010). Environmental Biology. S. Chand and Company Ltd., New Delhi.
7. Simpson, M.G. (2006). Plant Systematics. Elsevier Academic Press, San Diego, CA, U.S.A.
8. Singh, G. (2012). Plant Systematics: Theory and Practice. 3rd edition. Oxford & IBH Pvt. Ltd., New Delhi.

9. Sambamurty A.V.S.S. (2005). Taxonomy of Angiosperms. I. K. International Pvt. Ltd., New Delhi.
10. Singh M. P. & Abbas S. G. Essentials of Plant Taxonomy and Ecology. Daya Publishing House, New Delhi.
11. Singh, V., Pande, P. C. & Jain, D. K. (2008). Taxonomy and Economic Botany. Rastogi Publications, Meerut.
12. Pandey, B. P. (2009). A Textbook of Botany Angiosperms. . S. Chand and Company Ltd., New Delhi.

Generic Elective Course

Paper Code: BOTG- 605

Paper Title: Phytochemistry (Theory)

Credit: 4

Unit I: 18 lectures

Collection of sample, identification, Extraction processes, Sample drying processes, Cold and hot solvent extraction (Soxhlet and otherwise) for analysis purpose

Unit II: 12 lectures

Concentration of extract (Rotary evaporation/ air drying) and retrieving of solvent

Unit III: 12 lectures

Solvent fractionation (using separating funnel and solvent from polar to non polar like methanol/Chlorophorm/isopropanol/butanol/hexane/water.

Unit IV: 18 lectures

Determination of each fraction for secondary metabolites.

1. Phenolic compounds Flavonoids/anthocyanin
2. Terpenes essential oils (Limonene/composite TLC)
3. Alkaloids (Aminoacids proteins (potato) or non-protein seed of Cucurbitaceae 2D paper chromatography)
4. Screening each fraction for plant pathogens or human pathogens
5. Further analysis for active ingredient

Paper Title: Phytochemistry (Practical)

Paper Code: BOTG- 606(P)

Credit: 2

The paper is a more practical based course so the teaching should be emphasized on explanation of the principles and demonstration. All possible experiments mentioned in the theory should be conducted in the laboratory.

Suggested Readings

1. Harborne. J.B. (1998).Phytochemical methods. A guide to modern techniques of Plant Anlysis. Chapman and Hall publication, London
2. Plumber, D. T. (2006). An introduction to practical biochemistry Tata-McGraw-Hill Publication, New Delhi
3. Shah, B.N. (2005). Text book of Pharmacognosy and phytochemistry. Cbs Publishers & Distributors-New Delhi
4. Egbuna, C., Chinenye, J. Stanley I. and Udedi, C. (2018). Phytochemistry: Fundamental, modern techniques and applications. Apple Academic Press. CRC press.