

**ANDHRA UNIVERSITY**

 **DEPARTMENT OF BOTANY**

**M.Sc. Botany – Syllabus (**With effect from **2021 - 2022** admitted batches)

|  |  |
| --- | --- |
| **3rd Semester - Theory.** |  |
| Core Paper 301 | Taxonomy of Angiosperms and Plant Resources Utilizationand Conservation |
| Core Paper 302 | Plant Development and Plant Reproduction |
| Core Paper 303 | Plant Ecology |
| Core Paper 304 | Plant Physiology |
| **Practical** |  |
| Practical Paper - V | Corresponding to Paper 301 &302 |
| Practical Paper - VI | Corresponding to Paper 303 &304 |
| **4th Semester - Theory.** |  |
| Core Paper 401 | Genetic Engineering of Plants and Microbes |
| Core Paper 402 | Evolution and Plant Breeding |
| Core Paper 403 | Plant Pathology |
| Core Paper 404 | Crop Physiology and Biotechnology |
| **Practical** |  |
| Practical Paper - VII | Corresponding to Paper 401 &402 |
| Practical Paper - VIII | Corresponding to Paper 403 &404 |

**Department of Botany, Andhra University, Visakhapatnam M.Sc. BOTANY(**With effect from **2021 - 2022** admitted batches)

PROGRAMME OUTCOMES (PO)

|  |  |
| --- | --- |
| PO 1: | Understand the scope and significance of the discipline |
| PO 2: | Develop interest in Biological Research |
| PO 3: | Develop a thirst to preserve the Natural resources and Environment |
| PO 4: | Make the students exposed to the diverse life forms |
| PO 5: | Appreciate and apply ethical principles to biological science research and studies |

PROGRAM SPECIFIC OUTCOMES (PSO)

|  |  |
| --- | --- |
| PSO 1: | Understanding and Identification of the flora within field enhances basics of plants |
| PSO 2: | Application of Botany in Agriculture is through study of Plant Pathology |
| PSO 3: | Understanding the ultra-structure and function of cell membranes and cell communication |
| PSO 4: | Molecular and physiological adaptations in plants in response to biotic and abiotic stress |
| PSO 5: | Understand the classification plant taxonomy, Plant Ecology, Plant Anatomy and Plant Physiology |

COURSE LEARNING OUTCOMES (LO)

|  |  |
| --- | --- |
| LO 1: | Through classroom teaching demonstration and hands on training of various tools andtechniques available in the field of recombinant DNA technology |
| LO 2: | Develop functional knowledge on differentiating diseases caused by virus, fungi and bacteria |
| LO 3: | The students will learn about diversity of species about “Bryophytes”, “Pteridophytes” and “Gymnosperms” |
| LO 4: | The students will be learning about various signal transduction mechanism in plants |
| LO 5: | Students will develop ethical principles to biological science research and studies |



**ANDHRA UNIVERSITY DEPARTMENT OF BOTANY M.Sc. BOTANY**

**Course Structure (w.e.f. 2020-2021)**

**(Modifications in BoS meeting held on 23-10-2020)**

|  |
| --- |
| **3rd Semester** |
|  | **Theory** |  |  |  |  |
| 1. | 301 | Taxonomy of Angiosperms andPlant Resource Utilization & Conservation | 20 | 80 | 100 | 4 |
| 2. | 302 | Plant Development and Plant Reproduction | 20 | 80 | 100 | 4 |
| 3. | 303 | Plant Ecology | 20 | 80 | 100 | 4 |
| 4. | 304 | Plant Physiology | 20 | 80 | 100 | 4 |
|  | **Practicals** |  |  |  |  |
|  | Practical -I | Taxonomy of Angiosperms and Plant Resource Utilization & Conservation &Plant Development and Plant Reproduction | 20 | 80 | 100 | 3 |
|  | Practical -II | Plant Ecology & Plant Physiology | 20 | 80 | 100 | 3 |
|  |  | MOOC -I |  |  |  | 2\* |
|  |  | Project |  |  |  | 4\* |
| **Total marks and credits for III semester** | **600** | **22** |
| **4th Semester** |
|  | **Theory** |  |  |  |  |
| 1. | 401 | Genetic Engineering of Plants and Microbes | 20 | 80 | 100 | 4 |
| 2. | 402 | Evolution and Plant Breeding | 20 | 80 | 100 | 4 |
| 3. | 403 | Plant Pathology | 20 | 80 | 100 | 4 |
| 4. | 404 | Crop Physiology and Biotechnology | 20 | 80 | 100 | 4 |
|  | **Practicals** |  |  |  |  |
|  | Practical -I | Genetic Engineering of Plants and Microbes & Evolution and Plant Breeding | 20 | 80 | 100 | 3 |
|  | Practical -II | Plant Pathology & Crop Physiology and Biotechnology | 20 | 80 | 100 | 3 |
|  |  | MOOC -II |  |  |  | 2\* |
|  |  | Intellectual Property Rights |  |  |  | 2\* |
|  |  | Value based soft skills |  |  |  | 2\* |
| **Total marks and credits for IV semester** | **600** | **22** |
| **Grand Total marks and credits for all 4 semesters (I,II,III, IV)** | **2400** | **88** |

M.Sc. Botany - Semester III

**Core Paper 301: TAXONOMY OF ANGIOSPERMS AND PLANT RESOURCES UTILIZATION AND CONSERVATION**

**(**With effect from **2021 - 2022** admitted batches)

|  |
| --- |
| **Theory:** Semester end examination 80marks + Average midterm examinations 20marks = **100****Practical**:Semester end examination 80 + internal assessment 20 marks = **100**. |
| **Course Objectives:** |
| 1. To the advanced concepts and principles of Taxonomy, evolutionary inference of Angiosperms.
2. To understand .Biodiversity
3. To know important orders and families of flowering plants,
4. To classify and the role of important characters
5. To utilize and conservation of Plant resources
 |
| **Course learning outcomes:** |
| 1. Student will learn about the Angiosperms
2. Understand Nomenclature and how is it governed by the ICN?
3. Important morphological characters delineate flowering plants
4. Different classification systems
5. Principles and applications of Molecular Taxonomy
 |

**THEORY**

|  |  |
| --- | --- |
| **1.** | Origin and evolution of Angiosperms. Fossil Angiosperms. Taxonomy and Systematics. Concepts of species. Taxonomic hierarchy - species, genus, family and other categories; Principles used in assessing relationship and delimitation of taxa and attribution of rank. Plantidentification, Plant nomenclature –Binomial nomnclature, Plant collection and Documentation. |
| **2.** | Brief analysis of the features and evolutionary tendencies noticed in the following groups: Ranales, Rosales, Centrospermae, Tubiflorae, Amentiferae, Helobiales, Liliflorae and Glumiflorae. Taxonomic evidences: embryology, cytology and phytochemistry. Taxonomic tools: herbaria, floras, botanical gardens, biochemicaland molecular techniques, computers and GIS (Geo Information Systems). Cladistics in taxonomy. Numerical taxonomy and Serotaxonomy. |
| **3** | Systems of Angiosperm classification: Phenetic versus Phylogenetic system, Relative merits and demerits of major systems of classification: Takhtajan, Cronquist and Thorne. Basic concepts of Molecular Systematics: Gene sequencing, Restriction site analysis, Allozymes etc., Angiosperm Phylogeny Group (APG IV} classification system, Relevance of Taxonomy toconservation, sustainable utilization of bioresources and ecosystem research. |
| **4.** | World centers of primary diversity of domesticated plants. The Indo-Burmese Centre, Plant Introductions and Secondary centers. Plant explorations. Origin of agriculture.Origin, evolution, Botany, cultivation and uses of :1. Food Crops : Wheat, Rice
2. Forage Crops :*Sorghum*, Red gram
3. Fibre Crops : Cotton, Jute
 |
|  | 1. Oil yielding crops : Groundnut, Coconut
2. Medicinal and aromatic crops :*Catharanthus, , Cymbopogan*
 |
| **5** | Green Revolution: benefits and adverse consequences. Ethnobotany: Introduction, concept, objectives and scope. Plant biodiversity: Concept, status in India, utilization and concerns, conservation of wild biodiversity Principles of conservation: Strategies for conservation, *In-situ* conservation: protected areas in India- reserves, wetlands, mangroves, *Ex-situ* conservation:principles and practices. Botanical gardens. BSI, ICAR and CSIR. |

**PRACTICAL**

|  |
| --- |
| **Exhibits/ Experiments/ Suggested Laboratory Exercises** |
| **Taxonomy** |
| **1.** | Description of a specimen from representative and locally available families. |
| **2.** | Description of a species based on various specimens to study intraspecific variation: A collective exercise. |
| **3.** | Description of various species of a genus: location of key character and preparation of keys at genetic level. |
| **4.** | Location of key characters and use of keys at family level. |
| **5.** | Field trips within and around the campus; compilation of field notes and preparation of herbarium sheets of such plants, wild or cultivated, as are abundant. |
| **6.** | Training in using floras and herbaria for identification of specimens described in the class. |
| **7.** | Demonstration of the utility of secondary metabolites in the taxonomy of some appropriate genera. |
| **8.** | Comparison of different species of a genus and different genera of a family to calculate similarity coefficients and preparations of dendrograms. |
| **Plant Resources Utilization and Conservation** |
| **1.** | **Laboratory work:**1. Food crops : Wheat, Rice
2. Forage/fodder crops : *Sorghum*, Red gram
3. Fiber crops : Cotton, Jute
4. Oil yielding : Groundnut, Coconut
5. Medicinal and Aromatic plants :*Catheranthus, Withania, Cymbopogan*
 |
| **2.** | **Scientific visits:**The students should be taken to one of the following:A protected areas or Biosphere reserve or national park or sanctuary. A wetland.A mangrove.NBPGR (National Bureau of Plant Genetic Resources – New Delhi). BSI.CSIR Laboratory.FRI.Tropical Botanical Gardens. |

**Reference Books**

|  |  |
| --- | --- |
|  | **Taxonomy of Angiosperms** |
| **1.** | Mondal AK. 2011. **Advanced Plant Taxonomy**. New Central Book Agency Pvt. Ltd., Kolkata. |
| **2.** | Simpson MG. 2006. **Plant Systematics**. Elsevier Academic Press, California, USA. |
|  | . |
| **3** | Takhtajan AL. 1997. **Diversity and classification of Flowering Plants**. Columbia University Press, New York. |
| **4.** | Zomlefer WB. 1994. **AGuide to flowering plant families**. University of California Press, USA. |
| **5.** | Woodland DW. 1991. **Contemporary Plant Systematics.** Prentice Hall, New Jersey. |
| **6.** | Stace CA. 1989. **Plant Taxonomy and Biosystematics** .2ndEdition. Edward Arnold Ltd., London. |
| **7.** | Jones SB Jr. and Luchsinger AE. 1986. **Plant Systematics.** 2ndEdition. McGraw Hill Book Co., New ork. |
| **8.** | Radford AE. 1986. **Fundamentals of Plant Systamatics**. Harper and Row Publications, USA. |
| **9.** | Heywood VH and Moore DM. 1984. **Current concepts in Plant Taxonomy**. Academic Press, London. |
| **10.** | Davis PH and Heywoos VH. 1973. **Principles of Angiosperms Taxonomy**. Robert E Kreiger Pub. Co., New York. |
| **11.** | Harrison HJ. 1971. **New concepts in Flowering Plant Taxonomy**. Hieman Educational Books Ltd., London. |
| **12.** | Jones AD and Wilbins AD. 1971. **Variations and Adaptations in Plant species.**Hiemen and Co., Educational Books Ltd., London. |
| **13.** | Grant V. 1971. **Plant Biosystematics**. Academic press, London. |
| **14.** | Solbrig OT. 1970. **Principles and Methods of Plant Biosystamatics**. Macmillan, London. |
| **15.** | Heslop-Harrison J. 1967. **Plant Taxonomy**. English language Books Soc. and Edward Arnold Pub. Ltd., U.K. |
|  | **Plant Resource Utilization And Conservation** |
| **16.** | Sambamurthy AVSS and Subramanyam NS. 2000. **Economic Botany of Crop Plants**. Asiatech Publishers, Inc., New Delhi. |
| **17.** | Conway G. 1999. **The Doubly Green Revolution:Food for All in the 21st Century**. Comstock Publishing Associates, New York. |
| **18.** | Kocchar SL. 1998. **Economic Botany of the Tropics**. 2nd Edition. Mac Millan India Ltd., Delhi. |
| **19.** | Plant Wealth of India 1997. Special Issue of Proceedings Indian National Science Academy B-63. |
| **20.** | Sharma OP. 1996. **Hills Economic Botany**. (Late Dr. A.F. Hill, adapted by O.P. Sharms). Tata McGraw Hill Co., Ltd., New Delhi. |
| **21.** | Frankel OH, Brown AHD and Burdon JJ. 1995. **The conservation of Plant Diversity**. Cambridge University Press, Cambridge, UK. |
| **22.** | Paroda RS and Arora RK. 1991. **Plant Genetic Resources Conservation and Management.** IPGRI (Publication) South Asia Office, C/o. NBPGR Pusa Campus, New Delhi. |
| **23.** | Thakur RS, Puri HS and Hussain A. 1989. **Major Medicinal Plants of India. Central Institute of Medicinal and Aromatic Plants**. CSIR, Lucknow. |
| **24.** | Council of Scientific & Industrial Research 1986. **The useful plants of India. Publications and Information Directorate**. CSIR, New Delhi. |

Core Paper 302: PLANT DEVELOPMENT AND PLANT REPRODUCTION

**(**With effect from **2021 - 2022** admitted batches)

|  |
| --- |
| **Theory:** Semester end examination 80marks + Average midterm examinations 20marks = **100****Practical**:Semester end examination 80 + internal assessment 20 marks = **100**. |
| **Course Objectives:** |
| 1. To provide knowledge on Simple and complex tissues of plants
2. To gain the knowledge in Shoot and Root apical meristems, secondary growth and anomalous secondary growth in dicot and monocot plant
3. This educates the student in Pollination and pollen stigma interactions and fertilization in plant.
4. To gain the knowledge in fertilization and post fertilization events in Plants.
 |
| **Course learning outcomes:** |
| 1. Student can learn about different types of tissues in plant, Root apical meristems, shoot apical meristems and Root – Shoot transition
2. Student can learn about Phyllotaxy, Anomalous secondary growth in dicot and monocot stems.Floral development.
3. Student can learn about Pollination, Pollen pistil interactions, self-incompatibility, male and female gametophyte development and fertilization
4. Student can learn about different post fertilization events (Endosperm, Embryo development

Polyembryony; apomixis, parthenocarpy, Seed dormancy. |

THEORY

|  |  |
| --- | --- |
| Unit : 1 | Simple and complex tissues. Epidermis– stomata, trichomes. Secretory cells and tissues. Vascular tissue development: development and structure of the primary xylem, primary phloem, secondary xylem, secondary phloem. Root- shoot transition. Root development: organization of root apical meristem (RAM), cell fates and lineages, tissue differentiation. Lateral roots, root hairs, root microbe interactions. Cambium–structure, cell types, development of vascular cambium, cork cambium– structure of its derivatives, bark. |
| Unit : 2 | Shoot development: organization of the shoot apical meristem (SAM), cytological and molecular analysis of SAM. Leaf growth and differentiation: Differentiation of epidermis and mesophyll. Structure of foliage leaves and modified leaves. Phyllotaxy. Anomalous secondary growth in dicot and monocot stems.Floral development taking the examples of homeotic mutants in *Arabidopsis* and *Antirrhinum*. |
| Unit : 3 | Pollination: mechanisms and vectors. Pollen-pistil interaction–structure of the pistil, pollen-stigma interaction. Self-incompatibility: sporophytic, gametophytic, different methods to overcome self-incompatibility. Fertilization: pollen germination, pollen tube growth and guidance, entry of pollen tube into the embryo sac, pollen tube discharge, syngamy and triple fusion, polyspermy and hetero fertilization. |
| Unit : 4 | Male gametophyte: structure of anther, microsporagenesis, Types and role of tapetum, pollen development, sperm dimorphism, pollen embryo sacs and compound pollen grains. Pollen allergy. Female gametophyte: types of ovule, development of ovule, megasporogenesis, types of embryo sacs, organization of the embryo sac – ultra structure of the embryo sac cells. |
| Unit : 5 | Post-fertilization events: endosperm– development, types, functions, endosperm - embryo relationship. Embryo development–Johanson and Soueges systems; Types.Polyembryony; apomixis; parthenocarpy. Storage proteins of endosperm and embryo– LEA proteins. Seed dormancy, overcoming seed dormancy. |

PRACTICAL

|  |
| --- |
| **Exhibits/ Experiments/ Suggested Laboratory Exercises** |
|  | **Plant Development** |
| **1** | Microscopic examination of transverse sections of leaves such as *Nerium* and Maize to understand the internal structure of leaf tissues and trichomes, glands etc. Study of the C3 and C4 anatomy of plants |
| **2** | Study of epidermal peels of different kinds of leaves to study the development and nature stomata, computing stomatal index. |
| **3** | Study of elements of wood from macerations and sections taken in three planes T.S., T.L.S. and R.L.S |
| **4** | Study of the anomalous structure of the stems of Aristolochia, Achyranthes, Bignonia, Boerhaavia, Leptadenia and Dracaena. |
|  | **Plant Reproduction** |
| **1** | Study of microsporogenesis and gametogenesis in sections of anthers. |
| **2** | Tests for pollen viability using stains and *in-vitro* germination. |
| **3** | Embryo sac development through examination of permanent stained serial sections. |
| **4** | Study of nuclear and cellular endosperm through dissections and staining. |
| **5** | Isolation of different stages of embryo development from suitable seeds. |

Reference Books

|  |  |
| --- | --- |
|  | **Plant Development** |
| **1** | Pullaiah T, Naidu KC, Lakshminarayana K and Hanumantha Rao B. 2007.**PlantDevelopment**. Regency Publications, New Delhi. |
| **2** | Fosket DE. 2004. **Plant Growth and Development. A Molecular approach.** Academic Press, San Diego. |
| **3** | Howell SH. 1998. **Molecular Genetics of Plant Development**. Cambridge University Press, |
| **4** | Fahn A. 1982. **Plant Anatomy**. 3rd edition. Pergamon Press, Oxford |
|  | **Plant Reproduction** |
| **1** | Pulliah T, Lakshminarayana K and Hanumantha Rao B. 2008. **Plant Reproduction**. Scientific Publishers, Jodhpur, India. |
| **2** | Bhojwani SS and Bhatnagar SP. 2000. **The Embryology of Angiosperms**. 4th revised and enlarged edition. Vikas Publishing House, New Delhi. |
| **3** | Raghavan V. 1999. **Developmental Biology of Flowering Plants**. Springer – Verlag, New York. |
| **4** | Raghavan V. 1997. **Molecular Embryology of Flowering Plants**. Cambridge University Press, Cambridge. |

M.Sc. Botany – Semester III

**Core paper 303: PLANT ECOLOGY (**With effect from **2021 - 2022** admitted batches)

|  |
| --- |
| **Theory:** Semester end examination 80marks + Average midterm examinations 20marks = **100****Practical**:Semester end examination 80 + internal assessment 20 marks = **100**. |
| **Course objectives:** |
| 1. To study the geographical distribution, diversity and abundance of organisms.
2. To study the biological productivity of nature and its relationship with mankind.
3. To study the inter-relationship between organisms in population and communities.
4. Temporal changes in the occurrence, abundance and activities of organisms.
5. Conservation and management of natural resources and pollution
 |
| **Course learning outcomes** |
| 1. Understanding populations in terms of diversity, habitat, niche and growth rates.
2. Student learns about ecosystems and populations.
3. Student learn about interactions in the community in terms of competition and predation
4. Student learns about succession and climax communities.
5. Student learns about biodiversity and its conservation.
6. Exploring ecological problems and understanding of the greenhouse effect, global warming and climate change.
 |

THEORY

|  |  |
| --- | --- |
| Unit 1 | Habitat and niche: concept of habitat and niche, niche width and overlap, fundamental and realized niche, resource partitioning, character displacement.Population Ecology: characteristics of a population, population growth curves, population regulation, life history strategies (r and k selection), concept of meta population, demes and dispersal, interdemic extinctions, age structured population. |
| Unit 2 | Species interactions: types of interactions, interspecific competition, herbivory, carnivory. Ecological succession: types, mechanisms, changes involved in succession, concept of climax. Hydrosere and Xerosere.Community ecology: nature of communities, communities’ structure and attributes, levels of species diversity and its measurement, Diversity indices, edges and ecotones, community classification. |
| Unit 3 | The environment: physical environment, biotic environment and abiotic environment. Ecology and human welfare. Climate, soil and vegetation patterns of the world: life zones, major biomes, vegetation and soil types of the world.Climate change– greenhouse gases, ozone layer and ozone hole, consequences of climate change. Biodiversity status, monitoring and documentation, major drivers of biodiversity change. |
| Unit 4 | Ecosystem: structure and function. Energy dynamics. Mineral cycling (carbon, nitrogen and phosphorus). Primary production and decomposition. Structure and function of some Indian ecosystems– Terrestrial (forest, grassland) and aquatic (fresh water, marine, estuarine).Biogeography: Major terrestrial biomes. Theories of island biogeography. Bio geographical zones of India. |
| Unit 5 | Conservation biology: principles of conservation, major approaches to management. Indian case studies on conservation, management strategy (Biosphere reserves, Project tiger),biodiversity management approaches. Applied ecology: Environmental pollution –air, water and soil, kind’s sources, quality parameters. Effects on plant ecosystems. |

PRACTICAL

|  |
| --- |
| **Exhibits/ Experiments/ Suggested Laboratory Exercises** |
| 1. | To study the stratification of plants in botanical gardens. |
| 2. | To prepare life forms of botanical gardens of college campus. Compare the biological spectrum of college campus with normal biological spectrum. |
| 3. | To estimate the frequency of plants in the college campus. |
| 4. | To estimate the relative frequency of plants in the college campus. |
| 5. | To estimate the density of a plant species in the college campus. |
| 6. | To estimate the relative density of a plant species in college campus |
| 7. | To determine the minimal size and number of quadrats required for reliable estimate of biomass in grass land. |
| 8. | To determine the basal area of a plant species in the campus. |
| 9. | To determine the important value index (IVI) of plant species in the campus. |
| 10. | To estimate IVI of the plant species in a woodland using point center quarter methods. |
| 11. | To determine plant diversity indices (Shamon - Wiener) continuum of dominance, species richness, equitability and biodiversity of species in the campus. |
| 12. | To estimate rate of carbon dioxide evolution from different soils using soda lime or alkali absorption method. |
| 13. | To study environmental impact of a given developmental activity using check list as a EIA method. |
| 14. | Enumeration in pond ecosystems. |
| 15. | To study the composition of woodland ecosystem. |
| 16. | Demonstration of chemical energy stored in leaves which was the transformed from radiation energy. |
| 17. | Estimation of biomass of cropland plots. |
| 18. | Estimation of chlorophyll. |
| 19. | Determination of leaf area index methods with plain graph sheets. |
| 20. | To determine the water holding capacity of soil collected from different locations |

Reference Books

|  |  |
| --- | --- |
| 1 | American Public Health Association American Water Works Association. 2013. Standard Methods for the Examination of Water and Waste Water. General Books LLC, USA. |
| 2 | Sharma PD. 2007. Ecology and Environment. Rastogi Publications, Meerut. |
| 3 | Sharma PD. 2001. Ecology and Environment. Rastogi Publications, Meerut. |
| 4 | Smith RL. 1996. Ecology and field Biology. Harper Collins, New York. |
| 5 | Sokal RR and Rohit FJ. 1995. Biometry. W.H. Freeman and Co., New York. |
| 6 | Batra NK. 1992. Treatise on Plant Ecology. Pradeep Publications, Delhi. |
| 7 | CJ. 1989. Ecological Methodology. Harper and Row, New York, USA. |
| 8 | Ludwig JA and Reynolds JF. 1988. Statistical Ecology. Wiley, New York. |
| 9 | Magurran AE. 1988. Ecological Diversity and its measurement. Croom Helm, UK. |
| 10 | Moore PD and Chapman SB. 1986. Methods in Plant Ecology. Blackwell Scientific, Oxford, UK. |
| 11 | Pielow EC. 1984. The interpretation of Ecological Data. John and Wiley Sons, USA. |
| 12 | Muller – Dombois D and Ellenberg H. 1974. Aims and Methods of Vegetation Ecology. Blackburn Press, New Jersey. |
| 13 | Odum PE. 1971. Fundamentals of Ecology. 3rdEdition. W. B. Sounders, Philadelphia. |
| 14 | Dansemmire RF. 1968. Plant Communities. Horpes and Row, New York. |
| 15 | Misra R. 1968. Ecology Work Book. Oxford and IBH Publishing Co., New Delhi. |
| 16 | Ambasht RS and Ambasht NK. AText Book Plant Ecology. CBS Publishers and distributors, New Delhi. |

M.Sc. Botany – Semester III

Core Paper 304: PLANT PHYSIOLOGY

(With effect from 2021-2022 admitted batches)

|  |
| --- |
| **Theory:** Semester and examination 80 marks+ average midterm examinations 20 **marks=100****Practical:** Semester and examination 80 marks + internal assessments 20 marks**=100** |
| **Course Objectives** |
| 1. To create awareness about the stomatal physiology.
2. To understand the students the role of Phytohormones.
3. To create awareness about the process of water transport in plants.
4. To understand students about the nitrogen fixation.
5. To create awareness about different types of stress.
 |
| **Course Specific Objectives** |
| 1. Student can learn about plant water relations.
2. Student can learn about abiotic stress facing by plants.
3. Student can learn about the plant regulators.
4. Acquire the knowledge in Enzyme kinetics.
5. Acquaint the knowledge about Biotic and Abiotic stress.
 |

THEORY

|  |  |
| --- | --- |
| Unit 1. | Plant water Relations: Free energy and chemical potential, osmotic potential, water potential and its determination, Active and Passive absorption of water, Stomatal physiology and mechanisms of stomatal opening and closing, Soil-plant-atmosphere-continuum concept (SPAC) and mechanism of water transport. Mineral nutrition: Passive and Active uptake of ions, translocation of minerals in plants, Essential elements: Their functions and symptoms of mineral deficiency, importance of foliar nutrition. |
| Unit 2. | The flowering process: Photoperiodism and its significance, mechanisms of floral induction. Physiology seed germination. Plant growth regulators and elicitors: Biosynthesis, physiological effects and mechanism of action of Auxins, Gibberellins, Cytokinins, Ethylene, Abscisic acid, Brassinosteroids, Polyamines, Jasmonic acid and Salicylic acid. |
| Unit 3. | Photosynthesis: Photosynthetic pigments and light harvesting complexes, photooxidation of water, mechanisms of electron and proton transport, structure, synthesis and function of ATP. Carbon assimilation-the Calvin cycle, photorespiration and its significance, the C4 cycle and CAM pathway. |
| Unit 4. | Respiration: Glycolysis, the TCA cycle, electron transport and ATP synthesis, pentose phosphate pathway, glyoxylate cycle, alternative oxidase system and Lipid metabolism. Michaelis-Menten Equation and its significance, Mechanism of enzyme action. Nitrogen metabolism: Nitrogen fixation studies, biosynthesis of amino acids and proteins. |
| Unit 5. | Stress Physiology: Plant responses to biotic and abiotic stress, mechanisms of biotic and abiotic stress tolerance, water deficit and drought resistance, salinity stress, metal toxicity, heat stress and oxidative stress. |

PRACTICAL

|  |
| --- |
| **Exhibits/ Experiments/ Suggested Laboratory Exercises** |
| 1. | Determination of osmotic potential. |
| 2. | Determination of water potential. |
| 3. | Demonstration of osmosis. |
| 4. | Determination of root pressure. |
| 5. | Effects of high and low temperatures upon the permeability of the cytoplasmic membranes. |
| 6. | Determination of suction force due to transpiration. |
| 7. | Stomatal frequency and stomatal index of leaves. |
| 8. | Rate of transpiration in leaves by cobalt chloride paper method. |
| 9. | Determination of amylase activity |
| 10. | Extraction and separation of chloroplast pigments by paper chromatographic method |
| 11. | Determine chlorophyll a / chlorophyll b contents in C3 and C4 plants by spectrophotometric method |
| 12. | Determination of Hill reaction |
| 13. | Determination of rate of Aerobic respiration by continuous current method |
| 14. | Determination of rate of Anaerobic respiration by continuous current method |
| 15. | Determination of catalase activity |

REFERENCES

|  |  |
| --- | --- |
| 1 | Noggle GR and Fritz GJ. 1977. Introductory plant physiology |
| 2 | Reinert J and Bajaj YPS. 1977. Plant Cell, Tissue and Organ Culture. Springer – verlag, Berlin |
| 3 | Lange OI, Kappen L and Schule DD. 1976. Water and Plant Life |
| 4 | Burris RH and Black CC (ed) 1975. CO2 Metabolism and Productivity of Plants |
| 5 | Evans IT. 1975. Crop Physiology |
| 6 | Major AM and Mayber P. 1975. The germination of seeds. 2nd Edition |
| 7 | Mayber PA and Gele J. (ed) 1975. Plants in Saline Environments |
| 8 | Ashston and Crafts A. 1973. Mode of Action of Herbicides |
| 9 | Epstein E. 1972. Mineral Nutrition of Plants: Principles and Perspectives |
| 10 | Fogg GK. 1972. Photosynthesis |
| 11 | Hillman WS. 1972. The Physiology of Flowering |
| 12 | Kozlowski TT. (ed) 1972. Seed Biology. 3 Vols |
| 13 | Levitt J. 1972. Response of Plants to Environmental Stresses |
| 14 | Hatch MD, Osmond CB and Slatyer RO (ed) 1971. Photosynthesis and Photorespiration |
| 14 | Gregory RPF. 1971. Biochemistry of Photosynthesis |
| 16 | Zelitch I. 1971. Photosynthesis, Photorespiration and Plant Productivity |
| 17 | Gollek B. (ed) 1970. Structure and Function of Plant Cells in Saline Habitats. |
| 18 | Kozlowski TT. (ed) 1968. Water Deficit and Plant Growth |
| 19 | Annual Review of Plant Physiology. 1950. Vol. – Annual Reviews Inc., Stanford |

Model Question Paper

M.Sc. Botany – Semester IV

Core Paper 401: GENETIC ENGINEERING OF PLANTS AND MICROBES

(With effect from 2021-2022 admitted batches)

|  |
| --- |
| **Theory:** Semester and examination 80 marks + average midterm examinations 20 **marks=100****Practical:** Semester and examination 80 marks + internal assessments 20 marks**=100** |
| **Course Objectives** |
| 1. To provide a contextual and inquiry based learning of modern day advances in the field of recombinant DNA technology
2. To understand methods of Gene transfer
3. To know the different types of Vectors
4. To produce transgenic plants.
5. To have a concept on Bioinformatics
 |
| **Course Specific Objectives** |
| Students will acquire understanding of:1. Basic principles and modern age applications of recombinant DNA technology and proteomics.
2. Learning molecular and technical skills along with applications of the instrumentation.
3. Designing/conducting experiments and analyzing experimental data.
4. Ethics of Recombinant DNA Technology and proteomics.
 |

THEORY

|  |  |
| --- | --- |
| Unit 1. | Basics of rDNA technology: restriction enzymes–types, nomenclature, mechanism of action. Methodology of rDNA molecule synthesis–joining overlapping ends, blunt end joining, polylinkers. Vectors–features. Cloning vectors– plasmids, viral DNA, cosmids, bacterial andyeast artificial chromosomes (BACs and YACs). Expression vectors. |
| Unit 2. | Bacterial transformation. *In-vitro* packaging. Recognition of transformants–antibiotic resistance, *Lac Z*gene based selection. Genomic library, cDNA library. Methods of gene transfer in plants: electroporation, gene gun, *Agrobacterium* mediated– binary and cointegrative vector based. Chloroplast transformation. |
| Unit 3. | Classical examples of successful cases of transgenic plants– fungal, bacterial, viral and Insect tolerance (BT and proteinase inhibitors), herbicide tolerance, abiotic stress tolerance, male sterility– Barnase-Barstar. Quality improvement –golden rice, lateripening tomatoes(FlavrSavr). |
| Unit 4. | Techniques in genetic engineering: Blotting techniques– Southern, Northern and Western blotting, radioactive and non-radioactive labeling, detection of hybridization. *In-situ* hybridization– technique, radioactive and non-radioactive probes, enzyme and fluorescence detection methods (FISH), applications of the technique. PCR– technique, types, applications. DNA sequencing– basic principle of Sanger’s method, automated DNA sequencing, high throughput DNA sequencing. DNA fingerprinting–hybridization based (RFLP), PCR based (RAPD, AFLP). Restriction mapping. Microarray technique and its applications. Sequencing genomes–whole genome sequencing, shot gun sequencing. Next generation sequencing– 454sequencing |
| Unit 5. | Plant growth promoting bacteria – nitrogen fixers, siderophores, phytoharmone production. Genetic improvement of industrially important microbes for production of useful products – biopesticides, biofertilizers, antibiotics. Intellectual Property Rights, farmer’s rights. Patents. Ethical and environmental issues in genetic engineering. Bioinformatics: Scope. Data bases– types, Genbank, PIR, PDB. An account of NCBI. Web based tools for sequence searches – BLAST. Genome projects, genome annotation, gene annotation, features of the genome of *Arabidopsis*, rice. Genomics– structural genomics, comparative genomics, functionalgenomics. Molecular phylogeny and phylogenetic trees. |

PRACTICALS

|  |
| --- |
| **Exhibit/Experiment** |
| **1.** | Isolation of plasmid DNA |
| **2.** | Bacterial transformation and identification of transformation |
| **3.** | Plant DNA isolation |
| **4.** | Restriction enzyme digestion and gel electrophoresis |
| **5.** | Assignments on the syllabus |
| **6.** | Pictorial demonstration of the various techniques |

Reference Books

|  |  |
| --- | --- |
| **1.** | Glick BR, Pasternak JJ and Patten CL. 2010. **Molecular Biotechnology Principles and Applications of rDNA.** ASM Press, USA. |
| **2.** | Attwood TK, Smith DJP and Phukan S. 2009. **Introduction to Bioinformatics**. Pearson Education Ltd., UK. |
| **3.** | Sateesh MK. 2008. **Bioethics and Biosafety**. I K International Pvt. Ltd., Bangalore. |
| **4.** | Channarayappa. 2007. Molecular Biotechnology Principles and practices. Taylor and Francis, UK. |
| **5.** | Watson JD. 2007. **Recombinant DNA: Genes and Genomes: A short course**. W. H. Freeman, USA. |
| **6.** | Primrose SB and Twyman RM. 2006. **Principles of Genome Analysis and Genomics.**Blackwell publishers, USA. |
| **7.** | Lewin B. 2004. **Genes VIIII**. Pearson Prentice Hall, New Jersey. |
| **8.** | Chawla HS. 2002. **Introduction to Plant Biotechnology**. Oxford and I B H Publlishers, USA. |

M.Sc. Botany – Semester IV

Core Paper 402: EVOLUTION AND PLANT BREEDING

**(**With effect from **2021 - 2022** admitted batches)

|  |
| --- |
| **Theory:** semester and examination 80 marks+ average midterm examinations 20 marks=**100****Practical**: semester and examination 80 marks + internal assessments 20 marks=**100** |
| **Course objectives:** |
| 1. Hardy-Weinberg equilibrium
2. The relationship between natural selection and evolution
3. Crop improvement
4. Improved agronomic characters
5. Resistance against biotic and abiotic stress
 |
| **Course learning outcomes** |
| 1. Student can learn about Origin of life
2. Student can learn about Plant breeding methods
3. Student can learn about Bio statistical methods
 |

THEORY

|  |  |
| --- | --- |
| Unit 1. | Origin of life and unicellular evolution: Origin of basic biological molecules, abiotic synthesis of monomers and polymers, concept of Oparin and Haldane, experiment of Miller (1953). The first cell – evolution of prokaryote, Origin of eukaryotic cells– Endosymbiont theory, evolution of unicellular eukaryotes, anaerobic and aerobic metabolism. |
| Unit 2. | Theories of organic evolution: Lamarckism, Darwinism–concepts of variation, adaptation, struggle, fitness and natural selection, Synthetic theory, phyletic gradualism, punctuated equilibrium, concepts of neutral evolution.Molecular evolution: molecular divergence and molecular clocks–protein and nucleotide sequence analysis, gene duplication and divergence. Hardy-Weinberg equilibrium and its applications. |
| Unit 3. | Plant breeding: history, objectives, activities, important achievements and undesirable consequences. Organizations for crop improvement in India: ICAR, Agriculture universities, Central institutes for crop improvement, All India coordinated programs. |
| Unit 4. | Methods of breeding self-pollinated crops**:** Mass selection, Pureline selection, Pedigree method, Bulk method, Backcross method, Multiline varieties.Methods of breeding cross pollinated plants**:** Bulk Selection, Recurrent selection, Synthetic varieties, Hybridization. Breeding of vegetative propagated crops. Mutation breeding. Plant Introduction, domestication and acclimatization.Heterosis – genetic and molecular basis. |
| Unit 5. | Bio statistical methods**:** basic concept of parametric and non-parametric methods. Graphical representation. Probability distributions–Binomial, Poisson and Normal distributions. Measures of central tendency and dispersion. Concepts of confidence intervals, types of error, levels ofsignificance. Regression and correlation; t-test, chi square test, ANOVA. Basic introduction to multivariate statistics. |

PRACTICAL

|  |  |
| --- | --- |
| **1.** | Problems based on Hardy Weinberg law |
| **2.** | Line diagrams showing the plan of different methods of breeding self-pollinated crops- Mass selection, Pure line selection, Pedigree method, |
| **3.** | Line diagrams showing the plan of different methods of breeding cross pollinated crops- Bulk Selection, Recurrent selection. |
| **4.** | Methods of hybridization in rice, sorghum, bajra, cotton in standing crop in the field. |
| **5.** | Assignments with problems for computing measures of central tendency and dispersion- mean, median and mode, standard deviation and standard error. |
| **6.** | Assignment with problems for computing correlation and regression coefficients. |
| **7.** | Assignment with problems for implementing t test. |
| **8.** | Assignment with problems for computing ANOVA. |

References

|  |  |
| --- | --- |
| **1.** | Singh BD. 2012. **Plant Breeding: Principles and Methods.**Kalyani Publishers, Delhi. |
| **2.** | Stickberger MW. 1985. **Genetics**. McMillan, New York. |
| **3.** | Frey KJ. 1981. **Plant Breeding II**. Iowa State University Press, Oxford. |
| **4.** | Jones DA and Wilkins DA. 1971. **Variation and adaptation in plant species.** Heinemann Educational Books Ltd., London. |
| **5.** | Stebbins GL.1971. **Chromosomal evolution in Higher Plants**. Edward Arnold Publishers Ltd., London. |
| **6.** | Poehlman JM and Borthakur D. 1969. **Breeding Asian field crops: With Special Reference to Crops of India.** Oxford and IBH Pub. Co., Delhi. |
| **7.** | Briggs FN and Knowles PF. 1967.**Introduction to Plant Breeding.** Reinhold Pub. Corp., New York. |
| **8.** | Brewbaker JL. 1964. **Agricultural Genetics**. Prentice-Hall, New Jersey, USA. |
| **9.** | Allard RW. 1961. **Principles of Plant Breeding.** 2ndEdition. John Wiley and Sons Inc., New York. |

M.Sc. Botany - Semester IV Core Paper 403: PLANT PATHOLOGY

**(**With effect from **2021 - 2022** admitted batches)

|  |
| --- |
| **Theory:** Semester end examination 80 marks + Average midterm examinations 20 marks = **100****Practical:** Semester end examination 80 marks + internal assessment 20 marks = **100**. |
| **Course Objectives:** |
| 1. To provide knowledge on importance, Classification, symptoms and control of plant diseases.
2. To gain the knowledge in Symptoms, etiology, epidemiology & control measures with reference to some Fungal, Bacterial and Viral diseases.
3. This educates the student in know about different stages in Infection phenomena.
4. To gain knowledge on Role of enzymes, toxins, Phytotoxins. Vivo toxins.
 |
| **Course learning outcomes:** |
| 1. Student can gain knowledge on importance, Classification, symptoms and control of plant diseases
2. Student gain knowledge on Symptoms, etiology, epidemiology & control measures with reference to some Fungal, Bacterial and Viral diseases
3. Student gain knowledge on different stages in Infection phenomena, Role of enzymes,

toxins, Phytotoxins and Vivo toxins. |

THEORY

|  |  |
| --- | --- |
| Unit : 1 | Importance of plant diseases, classification of plant diseases, causes of plant diseases, symptoms of plant diseases, post-harvest diseases. Dispersal of plant pathogens- Active and passive. Control of plant diseases: Cultural practices: field & crop sanitation, crop rotation, Chemical control: systematic & nonsystematic fungicides; and Biological control. Plant diseases management through host resistance: Vertical, horizontal, monogenic, polygenic, specific & general resistance. Development of resistant varieties. |
| Unit : 2 | Symptoms, etiology, epidemiology & control measures with reference to the following: Fungal diseases – Club root of crucifers, Damping off of seedlings. Leaf spot of turmeric, Ergot of bajra, Powdery mildew of Cucurbits, Whip smut of sugarcane, Grain smut of *Sorghum*, Bean rust, Coffee rust, Blast disease of rice, Wilt of cotton, Tikka disease of ground nut. |
| Unit : 3 | Bacterial diseases – Citrus Canker, Angular leaf spot of cotton, Bacterial leaf Blight of rice, Brown rot of potatoes. Viral and phytoplasmas diseases – Grassy shoot diseases of sugarcane, Little leaf of Brinjal, Rice Tungro. |
| Unit : 4 | Infection phenomena – pre penetration, penetration and post penetration. Factors affecting infection. Effect of environment on plant disease development – Temperature, humidity and light.. Defense mechanisms in plants: Pre–inflectional defense mechanisms, Post–inflectional defense mechanisms, Phytoalexins. Molecular basics of host pathogen interactions (fungi, bacteria & viruses) and genetic engineering for disease resistance |
| Unit : 5 | Role of enzymes in plant diseases – Pectic, Macerating, cellulolytic, Lignolytic, Proteolytic, Lypolytic enzymes and hemicelluloses, inactivation of enzymes Role of toxins in plant diseases– Phytotoxins. Vivo toxins, host specific patho toxins & nonspecific patho toxins. |

PRACTICAL

|  |
| --- |
| **Exhibits/ Experiments** |
| **1** | Study of symptoms, microscopic examination of diseased parts and identification of the pathogens involved in different plant diseases. Fungal diseases–Club root of crucifers, Damping off of seedlings. Leaf spot of turmeric, Ergot of bajra, Powdery mildew of Cucurbits, Whip smut of sugarcane, Grain smut of *Sorghum*, Bean rust, Coffee rust, Blast disease of rice, Wilt of cotton, Tikka disease of ground nut. Bacterial diseases–Citrus Canker, Angular leaf spot of cotton, Bacterial leaf Blight of rice, Brown rot of potatoes. Viral and phytoplasma diseases – Grassy shoot disease of sugarcane, Little leaf of brinjal, rice tungro. |
| **2** | Isolation of fungal pathogens from leaves. |
| **3** | Isolation of fungal pathogens from soil. |
| **4** | Extraction of pectolytic enzymes from a pathogen. |
| **5** | Extraction of cellulase enzyme from a pathogen. |
| **6** | Isolation of plant pathogen– bacteria. |
| **7** | Isolation (purification) of plant viruses. |

Reference Books

|  |  |
| --- | --- |
| **1** | Ravichandra NG. 2013. **Fundamentals of Plant Pathology**. PHI Learning Pvt. Ltd., Delhi. |
| **2** | Ronald PC. 2007. **Plant-Pathogen Interactions: Methods in Molecular Biology.** Humana Press, New Jersey. |
| **3** | Mehrotra RS.2006. **Plant pathology**. Tata McGraw Hill Publishing Co. Ltd., New Delhi. |
| **4** | Sharma PD. 2004. **Plant pathology**. Rastogi Publications, New Delhi. |
| **5** | Bilgrami S and Dubey HC. 1998. **A text book of modern Plant pathology.** Sangam Books Ltd., Mumbai. |
| **6** | Singh RS. 1990. **Plant diseases.** Oxford and IBH Publishing Co., New Delhi. |
| **7** | Butler EJ. 1973. **Fungi and diseases in plants**. Periodical Expert Book Agency, Delhi. |
| **8** | Rangaswamy G. 1972. **Disease of crop plants in India.** Prentice Hall of India, New Delhi. |
| **9** | Smith KM. 1968. **Plant viruses**. Methuen, London. |
| **10** | Mundkar BB.1967. **Fungi and Plant diseases.** McMillan and Co. Ltd., Calcutta. |
| **11** | Rangaswamy G. 1962. **Bacterial Plant Diseases in India**. Asia Publishing House, Bombay. |

M.SC. BOTANY - SEMESTER IV

COREPAPER 404: CROP PHYSIOLOGY AND BIOTECHNOLGY

(With effect from 2021-2022 admitted batches)

|  |
| --- |
| **Theory:**Semester and examination 80 marks+ average midterm examinations 20 marks**=100 Practical:**Semester and examination 80 marks + internal assessments 20 marks**=100** |
| **Course Objectives** |
| 1. To create awareness about the seed Biology.
2. To understand the Photosynthetic pathways.
3. To create awareness about the stress tolerance mechanism in plants.
4. To understand students role of Bioinformatics in crop improvement.
5. To create awareness about crop physiology.
 |
| **Course Specific objectives** |
| 1. Student can learn about synthetic seeds.
2. Student can apply genetic engineering techniques.
3. Student can learn about the plant tissue culture.
4. Acquires the knowledge in Bio informatics techniques.
5. Acquaint the knowledge about crop development.
 |

THEORY

|  |  |
| --- | --- |
| 1. | Biology of Seed: Seed germination, Seed reserves and nutritional quality, Phytohormones andseed development, Dormancy – factors effecting and regulations, Synthetic seeds. |
| 2. | Molecular biology of light reactions: Photosynthetic pathways, Biotechnological strategies to improve Photosynthesis, Yield components, Source – sink relationships. Signal transduction in higher plants: Receptors and G-proteins, Calcium – Calmoudulin cascade |
| 3. | Stress Physiology: Physiology and molecular biology of stress tolerance in response to water, salt and heavy metal stress. |
| 4. | Methods in Biotechnology: Plant Tissue culture techniques in crop improvement, Protoplast isolation and culture, somatic hybridization, soma clonal variations. Basic principles of recombinant DNA technique; Techniques for transferring genes into plants and its applicationsin crop improvement. |
| 5. | Potentials of Biotechnology: Molecular mechanism to confer herbicide resistance in crop plants. Genetic engineering to improve plant disease resistance. Genetic manipulation of crops for insect resistance, Genetic engineering of seed proteins and oils. Bioinformatics: Scope and importance of Bioinformatics, Genomics, Proteomics. Principles of microarray technology andits applications in crop improvement |

PRACTICAL

|  |
| --- |
| **Exhibit/Experiment** |
| 1 | Exercise-1: Chlorophyll absorption spectrum and quantitative determinations, assay of Hill reaction in isolated chloroplast. Crop growth analysis |
| 2 | Exercise-2: Determination of CO2 compensation points in some crop plants, Estimation of carbohydrate, protein and nucleic acid contents in plants |
| 3 | Exercise-3: Determination of the activities of some enzymes associated with Carbohydrates and protein metabolism |
| 4 | Exercise-4: Effect of nitrogen and potassium on the growth and yield of crop plants |
| 5 | Exercise-5: Leaf anatomy in relation to diversity in photosynthetic pathways |
| 6 | Exercise-6: Effect of water and salt stress on the accumulation of proteins |
| 7 | Exercise-7: Estimation of nitrogen, phosphorus and potassium |
| 8 | Exercise-8: Experiments to study the effect of water and salt stress on seed germination and seedling development |
| 9 | Exercise-9: Experiments to study the weed control using some common herbicides |
| 10 | Exercise-10: Polyacrylamide gel electrophoresis of proteins |
| 11 | Exercise-11: Isolation of DNA |
| 12 | Exercise-12: Polymerase chain reaction |
| 13 | Exercise-13: Isolation of explants, establishment and maintenance of callus; Sub-culture of callus. Study of Somaclonal variation |
| 14 | Exercise-14: Isolation and culture of single cells |
| 15 | Exercise-15: Experiments on herbicide resistance and disease resistance in plants |

REFERENCES

|  |  |
| --- | --- |
| 1 | Lebowitz RJ. 1995. **Plant Biotechnology, a laboratory manual**. Wm. C. Brown Publishers, Qubuque |
| 2 | Murray Meo – young. 1995. **Comprehensive Biotechnology. Vol . 1.** Pergamon Press Oxford |
| 3 | Marshall G and Walters O (ed) 1994. **Molecular Biology in Crop Protection.**Champman and Hall |
| 4 | Old RW and Primrose SB. 1994. **Principles of gene manipulation.** Blackwell Science |
| 5 | Salunkhe DK, Bhatt NR and Desai BB. 1990. **Post-Harvest Biotechnology of Flowers and Ornamental Plants**. N. Bayoprokash, Calcutta |
| 6 | es KE. (ed) 1988. **Genome Analysis**. IRI Press, Oxford |
| 7 | Pierik RIM. 1987. **Invitro Culture of Higher Plants**. MartinusNihoff Publishers, Dordrecht |
| 8 | Primrose SB. 1987. **Molecular Biotechnology**. Blackwell Scientific Publications |
| 9 | Day PR. 1986. **Biotechnology and Crop Improvement and Protection**. BCPC Publications |
| 10 | Mantell SH and Smith N (ed) 1983. **Plant Biotechnology**. Cambridge University Press, Cambridge |