DEPARTMENT OF BOTANY

SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE

M.Sc. Botany Syllabus

Based on National Education Policy 2020 (NEP)

(To be implemented from Academic Year 2023-24)

July 2023

1. Title of the Course: M.Sc. Botany
2. Faculty: Science and Technology
3. Implementation period: For M.Sc. Part-I: August 2023 onwards
   For M.Sc., Part-II: August 2024 onwards
4. Preamble:

Plants have been significant throughout the history of human evolution. Botany, a branch of science, helps us understand the plant kingdom. The human population has been projected to reach 9 billion in the year 2045. The study of plants has therefore become paramount with reference to their utilization as food and medicine. 'Botany with a twist' would be the new *mantra*. Climate change and urbanization has influenced fisheries, animal husbandry, agriculture, and forest produce. Water shortages, pollution, and irregular monsoons added, make the future implications appear bleak. Currently, only 12 plants under cultivation account for 75% of all the human calories. However, there are about 5,500 different varieties of edible plants. Botanists need to study these plants and use them to their utmost potential by gaining theoretical and applied knowledge. Integrating classical and modern botany to solve problems faced by the real world is a new challenge.

The M.Sc. (Botany) syllabi has been redesigned under the aegis of the National Education Policy (2020). Major emphasis has been laid on skill development through hands-on training. Industry and entrepreneurship-oriented skills have been emphasized. The teaching-learning process has been enhanced in a wholesome manner and novel examination and evaluation parameters have been included. On-Job-Training (OJT) has been made mandatory. This will allow students to be aware of on-ground realities and requisites from their first semester of the master's program. For example, during this training, students can directly interact with businessmen/technocrats. It is also envisaged that through these meaningful interactions, many students will develop interest to pursue their Ph.D. degrees.

The curriculum has a judicious mix of 'core' courses essential to understand the 'essence' of botany and a number of 'elective' courses. The 'core' courses involve taxonomy of lower and higher forms, plant biochemistry and physiology, plant genetics, plant development, plant ecology, plant cell and molecular biology and a number of 'electives' spanning across botany and its interfaces with various disciplines as outlined in the structure to cover skill-based and applied aspects of botany.

This structure would help students align to the latest trends in research and technology at the interphase of agriculture, environmental sciences, pharmaceutical sciences and genetic engineering. This would attract students towards pure science disciplines and further help enhance their employability skills. The NEP structure envisages that a student can select 'elective' courses across any discipline and we feel that this would help break the silos and invigorate 'botany' as a whole, fostering many inter-disciplinary collaborations. It will also give an impetus to study the vast biodiversity in India.

We believe that such a course design would make the study of botany, a joyful and vibrant experience.

COURSE STRUCTURE FOR M. Sc. BOTANY PART I (SEMESTER I AND II)

Course Code	Course Name	Credits (44)
Credit Framework for Semester-I		
Major Core [10 (T) + 4 (P)]		
BOT 501 MJ	Taxonomy-I (Algae and Fungi)	2
BOT 502 MJ	Taxonomy-II (Bryophytes, Pteridophytes and Gymnosperms)	3
BOT 503 MJ	Plant Biochemistry and Physiology	3
BOT 504 MJ	Plant Genetics	2
BOT 505 MJP	Practicals based on BOT MJ501/502	2
BOT 506 MJP	Practicals based on BOT MJ503/504	2
	Total Major Core Credits	**14**
Major Elective (any one)		
BOT 510 MJ	Algal Bioprospecting	2
BOT 511 MJ	Plant Pathology	
BOT 512 MJ	Medicinal Mushroom Cultivation	
BOT 513 MJ	Post-harvest Technology	
BOT 514 MJ	Plant Breeding	
BOT 515 MJ	Industrial Botany	
BOT 516 MJ	Cultivation and Utilization of Medicinal Plants	
BOT 517 MJP	Practical Based on BOT 510 MJ	2
BOT 518 MJP	Practical Based on BOT 511 MJ	
BOT 519 MJP	Practical Based on BOT 512 MJ	
BOT 520 MJP	Practical Based on BOT 513 MJ	
BOT 521 MJP	Practical Based on BOT 514 MJ	
BOT 522 MJP	Practical Based on BOT 515 MJ	
BOT 523 MJP	Practical Based on BOT 516 MJ	
	Total Major Elective Credits	**4**
BOT 541 MN	Research Methodology	2
BOT 542 MNP	Practicals Based on BOT 541 MN	2
	Total Research Methodology Credits	**4**
	Total Credits Semester-I	**22**
Credit Framework for Semester-II		
Major Core [10 (T) + 4 (P)]		
BOT 551 MJ	Taxonomy-III (Angiosperms)	2
BOT 552 MJ	Plant Development-I	2
BOT 553 MJ	Plant Ecology	2
BOT 554 MJ	Cell Biology	2
BOT 555 MJ	Molecular Biology-I	2

BOT 556 MJP	Practicals based on BOT 551, 552 and 553 MJ	2
BOT 557 MJP	Practicals based on BOT 554 and 555 MJ	2
	Total Major Core Credits	**14**
BOT 560 MJ	Plant Tissue Culture	2
BOT 561 MJ	Plant Organism Interaction	
BOT 562 MJ	Plant Immunity	
BOT 563 MJ	Organic Farming	
BOT 564 MJ	Carbon Credit and Environment Impact Assessment	
BOT 565 MJ	Millet-based Nutraceuticals	
BOT 566 MJ	Aromatic Plants	
BOT 567 MJP	Practicals based on BOT 560 MJ	2
BOT 568 MJP	Practicals based on BOT 561 MJ	
BOT 569 MJP	Practicals based on BOT 562 MJ	
BOT 570 MJP	Practicals based on BOT 563 MJ	
BOT 571 MJP	Practicals based on BOT 564 MJ	
BOT 572 MJP	Practicals based on BOT 565 MJ	
BOT 573 MJP	Practicals based on BOT 566 MJ	
	Total Major Elective Credits	**4**
BOT 581 OJT/FP	On Job Training (OJT)/Field Project (FP)	4
	Total OJT/FP Credits	**4**
	Total Credits Semester-II	**22**

Course Code	**Course Name**	**Credits**
Credit Framework for Semester-III		
Major Core [10 (T) + 4 (P)]		
BOT-601-MJ	Molecular Biology-II	2
BOT-602-MJ	Tools and Techniques in Botany-I	2
BOT-603-MJ	Climate change and plants	2
BOT-604-MJ	Plant genetic engineering	2
BOT-605-MJ	Plant Development-II	2
BOT-606-MJP	Practicals based on MB-II & TTB-I	2
BOT-607-MJP	Practicals based on climate change and plants, plant genetic engineering & plant development - II	2
	Total Major Core Credits	**14**
Major Elective (any one)		
BOT-610-MJ(A)	Advanced Phycology- I	2
BOT-610-MJ(B)	Advanced Mycology-I	
BOT-610-MJ(C)	Angiosperms systematics - I	
BOT-610-MJ(D)	Plant Ecology-I	
BOT-610-MJ(E)	Advanced Plant Physiology-I	
BOT-610-MJ(F)	Pharmacognosy – I	
BOT-610-MJ(G)	Advanced Plant Genetics and Breeding-I	
BOT-610-MJ(H)	Plant Biotechnology- I	
BOT-611-MJP(A)	Practicals based on BOT-610-MJ(A) Advanced Phycology - I	2

BOT-611-MJP(B)	Practicals based on BOT-610-MJ(B) Advanced Mycology-I	
BOT-611-MJP(C)	Practicals based on BOT-610-MJ(C) Angiosperms systematics -I	
BOT-611-MJP(D)	Practicals based on BOT-610-MJ(D) Plant Ecology-I	
BOT-611-MJP(E)	Practicals based on BOT-610-MJ(E) Advanced Plant Physiology -I	
BOT-611-MJP(F)	Practicals based on BOT-610-MJ(F) Pharmacognosy-I	
BOT-611-MJP(G)	Practicals based on BOT-610-MJ(G) Advanced Plant Genetics and Breeding- I	
BOT-611-MJP(H)	Practicals based on BOT-610-MJ(H) Plant Biotechnology- I	
Total Major Elective Credits		4
BOT-631-RP	Research Project	4
Total Credits for Semester-III		22

COURSE STRUCTURE FOR M. Sc. BOTANY PART II (SEMESTER III AND IV)

Course Code	Course Name	Credits
Credit Framework for Semester-IV		
Major Core [8 (T) + 4 (P)]		
BOT-651-MJ	Bioinformatics and Biostatistics	2
BOT-652-MJ	Plant Evolution	2
BOT-653-MJ	Tools and Techniques in Botany-II	2
BOT-654-MJ	Biodiversity, conservation & utilization	2
BOT-655-MJP	Practicals based on Bioinformatics and Biostatistics and Plant Evolution	2
BOT-656-MJP	Practicals based on TTB-II and Biodiversity, conservation & utilization	2
Total Major Core Credits		**12**
Major Elective (any one)		
BOT-660-MJ(A)	Advanced Phycology- II	2
BOT-660-MJ(B)	Advanced Mycology-II	
BOT-660-MJ(C)	Angiosperms systematics - II	
BOT-660-MJ(D)	Plant Ecology-II	
BOT-660-MJ(E)	Advanced Plant Physiology-II	
BOT-660-MJ(F)	Pharmacognosy – II	
BOT-660-MJ(G)	Advanced Plant Genetics and Breeding-II	
BOT-660-MJ(H)	Plant Biotechnology- II	
BOT-661-MJP(A)	Practicals based on BOT-610-MJ(A) Advanced phycology - II	2
BOT-661-MJP(B)	Practicals based on BOT-610-MJ(B) Advanced Mycology-II	

BOT-661-MJP(C)	Practicals based on BOT-610-MJ(C) Angiosperms systematics -II	
BOT-661-MJP(D)	Practicals based on BOT-610-MJ(D) Plant Ecology-II	
BOT-661-MJP(E)	Practicals based on BOT-610-MJ(E) Advanced Plant Physiology -II	
BOT-661-MJP(F)	Practicals based on BOT-610-MJ(F) Pharmacognosy-II	
BOT-661-MJP(G)	Practicals based on BOT-610-MJ(G) Advanced Plant Genetics and Breeding -II	
BOT-661-MJP(H)	Practicals based on BOT-610-MJ(H) Plant Biotechnology- II	
	Total Major Elective Credits	4
BOT-681-RP	Research Project	6
	Total Credits for Semester-IV	22

SEMESTER I: CORE COURSES (Mandatory)		
BOT 501 MJ Taxonomy-I (Algae and Fungi) (2 Credits: 30 Lectures)		
Credit 1:Algae		**15L**
1.	Botanical nomenclature: International code of nomenclature for algae, fungi, and plants (ICN), classification system in algae	**2L**
2.	Cyanophyta: Introduction, thallus organization, cell ultrastructure, heterocyst development and function	**2L**
3.	Endosymbiosis and origin of eukaryotic algae	**1L**
4.	Chlorophyta: Structure and evolution of thallus, reproduction and life cycle with reference to orders of green algae	**3L**
5.	Charophyta: Thallus structure, reproduction and life cycle	**1L**
6.	Ochrophyta (Phaeophyceae): Thallus structure, reproduction and life cycle	**2L**
7.	Rhodophyta: Thallus structure, reproduction and life cycle	**2L**
8.	Bacillariophyta: Thallus structure, reproduction and life cycle	**1L**
9.	Euglenophyta: Thallus structure, reproduction and life cycle	**1L**
Credit 2: Fungi		**15L**
1.	Characters of fungi used for classification, system of classification by Ainsworth	**2L**
2.	Myxomycotina: Structure, Life cycle patterns of major classes	**2L**
3.	Mastigomycotina: Structure, Life cycle patterns of major classes	**2L**
4.	Zygomycotina: Structure, Thallus organization, and Evolution of sexual reproductive structures	**2L**
5.	Ascomycotina: Thallus organization, Centrum development, and Different types of ascocarps	**2L**
6.	Basidiomycotina: Tissue differentiation, Development of basidia and basidiospore	**2L**
7.	Deuteromycotina: Types of conidial ontogeny and fruiting body organization	**1L**
8.	Heterothallism, Heterokaryosis and parasexual cycle	**1L**
9.	Recent concept of origin and molecular phylogeny in fungi	**1L**

Suggested References

Algae:

1. Archibald, J. M., Simpson, A. G. B. and Slamovits, C. H. (eds.) (2017). *Handbook of the protists* (2nd ed.). Springer International Publishing AG, pp. 1657.
2. Barsanti, L. and Gualtieri, P. (2014). *Algae-anatomy, biochemistry, and biotechnology* (2nd ed.). CRC Press, Boca Raton, pp. 326.
3. Bellinger, E. G. and Sigee, D. C. (2015). *Freshwater algae: Identification, enumeration, and use as bioindicators* (2nd ed). John Wiley & Sons, Ltd., UK, pp. 275.
4. BrodieJ. and Lewis, J. (eds.) (2007). *Unravelling the algae: the past, present, and future of algal systematics(The Systematics Association Special Volume Series 75)*. CRC Press, Boca Raton, pp. 376.
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10. Lee, R. E. (2008). *Phycology* (4th ed.). Cambridge University Press, NY, pp. 547.
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12. Pereira, L. and Neto, J. M. (eds.) (2014). *Marine algae: Biodiversity, taxonomy, environmental assessment, and biotechnology*. CRC Press, Boca Raton, pp. 390.
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14. Sahoo, D. and Seckbach, J. (2015). *The algae world(Cellular origin, life in extreme habitats and astrobiology 26)*. Springer Science, Dordrecht, pp. 598.
15. Sarma, T. A. (2013). *Handbook of cyanobacteria*. CRC Press, Boca Raton, pp. 802.
16. Simpson, M. G. (2010). *Plant systematics* (2nd ed.). Elsevier Inc., NY, pp. 740.
17. Singh, P. K., Kumar, A., Singh, V. K. and Shrivastava, A. K. (eds.) (2020). *Advances in cyanobacterial biology*. Elsevier Inc., UK, pp. 403.
18. Turland, N. (2013). *The code decoded: A user's guide to the International Code of Nomenclature for algae, fungi, and plants* (Regnum Vegetabile 155). Koeltz Scientific Books, Germany, pp. 169.
19. Wehr, J. D., Sheath, R. G. and Kociolek, J. P. (eds.) (2015). *Freshwater algae of North America: Ecology and classification* (2nd ed.). Elsevier Inc., USA, pp. 1050.

Fungi:

1. Alexopoulus, C. J., Minms, C. W. and Blackwell, M. (1999). (4th Ed.) *Introductory Mycology*. Wiley, New York. Alford, R. A.
2. Deacon, J. W. (2006). *Fungal Biology* (4th Ed.) Blackwell Publishing, ISBN. 1405130660.
3. Kendrick, B. (1994). *The fifth kingdom* (paperback), North America, New York,Publisher: 3rd Ed., ISBN- 10: 1585100226.
4. Kirk et al., (2001). Dictionary of the fungi, 9th Ed., published Wallingford: CABI, ISBN: 085199377X.

5. Mehrotra, R. S. and Aneja, K.R. (1990). *An Introduction to Mycology.* New age Publishers, ISBN 8122400892.

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7. Webster, J. and Rpland W. (2007). *Introduction to Fungi* (3rd Ed.), CambridgeUniversity Press, 978-0-521-80739-5.

BOT 502 MJ Taxonomy-II (Bryophytes, Pteridophytes and Gymnosperms)
(3 Credits: 45 Lectures)

Credit 1: Bryophytes		**15L**
1	Introduction, general characteristics, distribution, diversity and economic importance of bryophytes	**3L**
2	Classification of bryophytes	**1L**
3	Distribution, morphology, anatomy and reproductive studies, inter-relationships and evolutionary trends in the following groups- (a) Hepaticae: Sphaerocarpales, Calobryales, Takkakiales,Marchantiales, Jungermanniales (b) Anthocerotae: Anthocerotales (c) Musci: Sphagnales, Andraeales, Polytrichales, Buxbaumiales,Funariales	**4L** **1L** **5L**
4	Fossil bryophytes, recent additions of bryophytes in the Indian flora	**1L**
Credit 2: Pteridophytes		**15L**
1	Introduction, diversity,affinities with gymnosperms and importance	**2L**
2	Systems of classification	**1L**
3	Evolution: telome, steles, sori, gametophytes	**2L**
4	Origin and evolution	**2L**
5	Distribution, morphology, anatomy, reproduction andinterrelationship of following orders– Psilotales, Lycopodiales, Isoetales, Equisetales, Ophioglossales, Marratiales, Osmundales, Filicales, Marsileales, Salviniales	**7L**
6	Alternation of generations, apogamy, apospory and heterospory	**1L**
Credit 3: Gymnosperms		**15L**
1	Characters, diversity, classification systems and affinities with other groups	**2L**
2	Distinguishing featuresofProgymnosperms, Pteridospermales, Cycadeoidales, Cycadales, Caytoniales, Glossopteridales, Pentoxylales, Cordiatales and Voltziales	**2L**
3	Morphology, anatomy, sporogenesis, gametogenesis, embryology, interrelationship betweenCycadales and Ginkgoales	**2L**
4	Morphology, anatomy, reproduction and interrelationship of Pinales/Coniferales,Taxales,Gnetales, Ephedrales and Welwitschiales	**6L**
5	Seed development in Gymnosperms	**2L**
6	Economic importance and taxonomic updates	**1L**

Suggested References:

Bryophytes

1. Cavers, F. (1976). *The inter relationships of the bryophyte*. S.R. Technic, Ashok Rajpath, Patna.
2. Chopra, R. N. and Kumar, P. K. (1988). *Biology of bryophytes*. John Wiley & Sons, New York, NY.
3. Kashyap, S. R. (1929). *Liverworts of The Western Himalayas And ThePanjab Plain Part 1* Chronica Botanica New Delhi.
4. Kashyap, S. R. (1932). *Liverworts of the Western Himalayas and the Panjab plain* (illusterated): Part 2 The ChronicaBoanica New Delhi. Bryophya central Book Depot.
5. Prem puri (1981). *Bryophytes: Morphology, Growth and Differentiation*, Atmaram and Sons, New Delhi.
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7. Udar, R. (1970). *Introduction to bryphyta*Shashidhar MalaviyaPrakashan Lucknow
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9. Smith, G. M. (1955) Cryptogamic Botany Bol. II
10. Watson, E.V. (1963) : British Mosses and Liverworts
11. Watson, E.V. (1964) : The Structure and life of Bryopytes
12. Goffinet, B. (2008). *Bryophyte biology*. Cambridge University Press.
13. Shaw, A. J., &Goffinet, B. (Eds.). (2000). Bryophyte biology. Cambridge University Press.
14. Tuba, Z., Slack, N. G., & Stark, L. R. (Eds.). (2011). *Bryophyte ecology and climate change*. Cambridge University Press.

Pteridophytes

1. Rashid A. (1999) An Introduction to Pteridophyta. Vikas Publishing house Pvt.Ltd. New Delhi.
2. Sharma O.P. (1990) Textbook of Pteridophyta. Mac Millan India Ltd., Delhi.
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6. SundaraRajan S. (1999) Introduction to Pteridophyta. New Age International Publishers, New Delhi.
7. Parihar N.S. (1977) Biology and morphology of the Pteridophytes. Central Book Depot.

Gymnosperms

1. Agashe S.N. (1995) Paleobotany, Oxford and IBH Publ. Co.Pvt. Ltd., New Delhi.
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3. Bhatnagar S.P. and Motia A. (1996) Gymnosperms. New Age International, New Delhi.
4. Biswas C. and Johri B.M. (1997) Gymnosperms. Narsa Publishing House, New Nelhi.
5. Chamberlain C.J. (1986) Structure and Evolution. CBS Publishers, New Delhi.
6. Eames E.J. (1983) Morphology of Vascular Plants. Standard University Press.
7. Johari M., Sneh Lata and Kavita Tyagi (2012) A Textbook of Gymnosperms. Dominant Publishers and Distributors, New Delhi
8. Rashid A. (1999) An Introduction to Pteridophyta. Vikas Publishing house Pvt.Ltd. New Delhi.
9. Sharma O.P. (1990) Textbook of Pteridophyta. Mac Millan India Ltd. Delhi.
10. Singh V.P. (2006) Gymnosperms (Naked seed plants): Structure and Development, Sarup and Sons, New Delhi.

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15. Surange K.R. (1966) Indian fossil Pteridophytes. Council of Scientific and Industrial research.
16. Parihar N.S. (1976) Biology and morphology of the Pteridophytes. Central Book Depot.

BOT 503 MJ Plant Biochemistry and Physiology
(3 Credits: 45 Lectures)

Credit 1: Enzymology, biomolecules and mineral nutrition		**15L**
1	Structure and properties of water, ionization of water, pH, buffers	1L
2	Bioenergetics: Free energy, changes in free energy during chemical reactions, entropy and enthalpy, high energy compounds	1L
3	Enzymology: Classification and properties of enzymes, Isoenzymes, coenzymes and cofactors, coupled reactions. Enzyme kinetics–substrate concentration and rate, competitive and non-competitive inhibitors. Covalent and allosteric regulation	3L
4	Biosynthesis and metabolism of amino acids, carbohydrates, fatty acids and lipids	3L
5	Mineral nutrition of plants: Cation-anion exchange capacity of soil, types of ion transporters, role of membrane potential in ion transport, passive and active transport, high and low affinity transporters	3L
6	Nitrogen: Uptake, assimilation and remobilization in plants, biological nitrogen fixation	2L
7	Phloem structure and function: Source and sink relationship, translocation of photoassimilates, phloem loading and unloading, composition of phloem sap	2L
Credit 2: Water uptake, photosynthesis and respiration		**15L**
1	Water uptake, transport and transpiration, stomatal physiology	2L
2	Photosynthesis: Photosynthetic pigments, organization of photosynthetic electron transport system, fluorescence and photochemistry, oxygen evolution, NADP Reduction, photophosphorylation	4L
3	Reduction of carbon dioxide: RuBPcase and Calvin cycle, photorespiration. CO_2 concentrating mechanisms in C4 and CAM plants	4L
4	Respiration: Glycolysis, citric acid cycle, pentose phosphate pathway, organization of mitochondrial electron transport system, ATP synthesis, respiratory control, anaerobic respiration	5L
Credit 3: Plant hormones and secondary metabolites		**15L**
1	Plant growth hormones: Structure, biosynthesis and metabolism of auxins, cytokinins, gibberellins, abscisic acid and ethylene, physiological role of hormones	8L
2	Photoperiodism and vernalization	3L
3	Secondary metabolite biosynthetic pathways: Terpenoids, phenolics, alkaloids	4L

Suggested References

1. Berg J.M., Tymoczko J.L., Stryrer L. (2002) Biochemistry. 5th Ed. Wlt. Freeman and Company, New York.
2. Buchanan B.B., Gruissem W., Jones R.L. (2000) Biochemistry and Molecular Biology of Plants. IK International, Mumbai.
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4. Goodwin T.W., Mercer E.I. (1998) Introduction to Biochemistry. CBS Publishers, New Delhi.
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5. Lawlor D.W. (2001) Photosynthesis in C3 and C4 Pathway.3rd Ed. Viva. New Delhi.
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7. Lincoln Taiz and Eduardo Zeiger (2010) Plant Physiology, 5th edition. Sinauer Associates, Inc. Publishers. Sunder land, USA.

BOT 504 MJ Plant Genetics
(2 Credits: 30 Lectures)

Credit 1: Qualitative and quantitative genetics		**15L**
1	Mendelian principles and extensions: Co-dominance, incomplete dominance, pleiotropy, genomic imprinting, penetrance, expressivity and phenocopy, sex- linkage, sex-limited and sex-influenced characters	**3L**
2	Inheritance of complex traits: Polygenic inheritance, heritability and its measurement	**3L**
3	Karyotype analysis, evolution and applications	**2L**
4	Structural alterations of chromosomes, complex translocation heterozygotes, Robertsonian translocations and their genetic implications	**3L**
5	Population genetics: Allele frequencies and genotype frequencies, random mating and Hardy-Weinberg principle and its implications, rate of change in gene frequency through natural selection, mutation, migration and random genetic drift	**4L**
Credit 2: Microbial genetics and linkage mapping		15L
1	Mutant phenotypes, methods of genetic transfers in bacteria: transformation, conjugation and transduction, mapping of bacterial genome by interrupted mating	3L
2	Phage genetics: Phage mutants, Lytic and lysogenic cycles in phages, genetic recombination in phages, mapping bacteriophage genome, fine structure analysis of *rII*gene in T4 bacteriophage	4L
3	Linkage and mapping in eukaryotes: Linkage and crossing over, recombination, Linkage maps, LOD score for linkage testing, mapping by 3-point test cross, tetrad analysis in yeast and *Neurospora*	8L

Suggested References

1. Atherly, A.G., Girton, J.R. and Mcdonald, J. F. (1999) The science of genetics. Sauders College Pub., Fort Worth, USA.
2. Hartl, D.L., Jones E.W. (2001). Genetics: Principle and analysis (4thedn) Jones and Barlett Pub., USA.

3. Khush, G S (1973) Cytogenetics of Aneuploids. Academic press New York, London.
4. Lewin, B. Genes VIII. Oxford, University press. New York, USA.
5. Russel, P.J. 1998. Genetics (5th edn) The Benjamin/ Cummins Pub. Co., Inc. USA.
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BOT 505 MJP Practicals Based on: BOT MJ 501 and BOT MJ 502
(2 Credits: 15 Practicals)

Practicals based on Algae		**3P**
1	Morphology and classification of Cyanophyta	**1P**
2	Morphology and classification of Chlorophyta	**1P**
3	Morphology and classification ofOchrophyta (Phaeophyceae) and Rhodophyta	**1P**
Practicals based on Fungi		**3P**
1	Comparative morphological and anatomical characters in Myxomycota, Zygomycotina and Mastigomycotina	**1P**
2	Comparative morphological and anatomical characters inAscomycotina, Basidiomycotina and Deuteromycotina	**1P**
3	ConstrMJion of Phylogenetic tree using MEGA software	**1P**
Practicals based on Bryophytes		**3P**
1	Taxonomic studies in Marchantiales: *Asterella, Plagiochasma, Targionia and Cyathodium*(any two)	**1P**
2	Taxonomic studies in Musci: *Sphagnum, Polytrichum, Pogonatum, Bryum*(any two)	**1P**
3	*Invivo/ in vitro* culture of Bryophytes	**1P**
Practicals based on Pteridophytes		**3P**
1	Taxonomic studies in Psilotales: *Psilotum, Tmesipteris*and Lycopodiales: *Lycopodium* (any two)	**1P**
2	Taxonomic studies in Filicales: *Anemia, Lygodium, Gleichenia, Ceratomium, Goniopteris, Phymotodes, Pteris, Acrostichum, Blechnum, Platycerum, Pteridum, Pleopeltis, Cheilanthus, Ceratopteris, Athyrium, Adiantum* (any two)	**1P**
3	Demonstration of*Azolla*cultivation	**1P**
Practicals based on Gymnosperms		**3P**
1	Taxonomic studies inCycadales and Ginkgoales	**1P**
2	Taxonomic studies in Coniferales	**1P**
3	Taxonomic studies inGnetales and Ephedrales	**1P**

BOT 506 MJP Practicals based on BOT MJ 503and BOT MJ 504 (2 Credits: 15 Practicals)		
Practicals based on BOT MJ 503 Plant Biochemistry and Plant Physiology		
1	Estimation of soluble proteins in germinating and non-germinating seeds by Lowry/Bradford method	1P
2	Estimation of total amino acids in seeds	1P
3	Estimation of ascorbic acid in ripe and unripe fruits	1P
4	Estimation of cytokinins using test system of greening of cotyledons	2P
5	Transduction of alpha-amylase activity by GA_3 in cereal grains	2P
6	Assay of nitrate reductase activity in plant tissues	2P
7	Effect of substrate concentration on K_m and V_{max} of invertase	2P
8	Effect of pH on enzyme activity	1P
9	Estimation of reducing sugars in developing fruits	2P
10	Estimation of starch in storage tissue	2P
11	Estimation of alpha-amylase activity in germinating seeds	2P
12	Estimation of invertase activity in plant tissues	2P
Practicals based on BOT 504 MJ Plant Genetics		
1	Preparation of somatic C- metaphase chromosomes and karyotype analysis in *Allium cepa*/*Aloe* sp.	2P
2	Study of meiotic configurations in *Zea mays*/*Allium cepa*, *Rhoeo* sp./*Aloe* sp., *Tradescantia s*sp. (prophase I, chiasma analysis)	2P
3	Study of chromosomal aberrations in irradiated plant material	1P
4	Study of polygenic inheritance	1P
5	Problems based on Mendelian inheritance and population genetics and linkage, estimation of gene and allele frequencies	2P
6	Tetrad analysis in *Neurospora crassa*	1P
7	Handling of *Drosophila melanogaster* for study of monohybrid, dihybrid, and sex-linked inheritance	1P
8	Study of monohybrid and dihybrid crosses and genetic interactions	1P
9	Linear differentiation of chromosomes through banding techniques:	2P

	C-Banding/G-Banding/Q-Banding	
10	PTC testing ability/tongue rollers-non rollers in humans	1P

SEMESTER I: ELECTIVE COURSES		
Sr. No.	**Topics Covered**	**Number of Lectures/ Practicals**
BOT 510 MJ Algal Bioprospecting (2 Credits: 30 Lectures)		
Credit 1: Cultivation of Micro-and Macroalgae		**15L**
1	Isolation methods, purification and maintenance of microalgae	**2L**
2	Growth curve studies, measurement of algal growth	**2L**
3	Continuous culture system, scaling-up at laboratory and open pond system	**3L**
4	Photobioreactors and biomass production in closed system	**1L**
5	Harvesting and drying of algal biomass	**2L**
6	Economics of microalgal production	**1L**
7	Cultivation of commercially important algae: *Spirulina, Chlorella, Porphyra, Kappaphycus, Gracilaria, Laminaria*	**4L**
Credit 2: Bioprospecting of Micro-and-Macroalgae		**15L**
1	Algae as food and nutritional supplements (SCP, PUFA, etc.), animal feed	**2L**
2	Blue green algal biofertilizer,seaweed liquid fertilizer(SLF) and their applications in agriculture	**2L**
3	Algal pigments of commercial value	**1L**
4	Sources of phlorotannins and their commercial applications	**1L**
5	Biofuel (biodiesel, hydrogen and bioethanol)production from algae	**2L**
6	Algal polysaccharides: Agar, alginates, carrageenan and their commercial applications	**3L**
7	Diatomite and its commercial applications	**1L**
8	Carbon sequestration by algae	**1L**
9	Algae in waste water treatment (Phycoremediation)	**1L**
10	Intellectual property rights associated with algal bioprospecting	**1L**

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BOT 517 MJP Practicals based on BOT 510 MJ
(2 Credits: 15 Practicals)

1.	Culturing of microalgae: Isolation, purification and maintenance of algal strains	**4P**
2.	Qualitative and quantitative analysis of algal lipids	**2P**
3.	Estimation of carotenoids from commercially important algae	**1P**
4.	Extraction and purification of phycocyanin/phycoerythrin from algae	**3P**

5.	Extraction of UV protective scytonemin from cyanobacteria	**2P**
6.	Extraction of phlorotannins from algal sample	**2P**
7.	Enrichment of algal cultures for mass production	**2P**
8.	Immobilization of algae for bioprospecting	**2P**
9.	Method for production of Single Cell Protein (SCP)	**2P**
10.	Preparation of Seaweed Liquid Fertilizer (SLF)	**2P**
11.	Survey of commercially available algal products	**1P**
12.	Algal growth measurements and growth curve studies	**2P**
13.	Lyophilization of algal samples and testing for viability	**2P**
14.	Preparation of BGA biofertilizer	**2P**
15.	Extraction and purification of agar-agar and alginates	**3P**
16.	Biphasic culturing of algae from soil samples	**2P**
17.	Isolation and identification of algae from oil-spills	**2P**
18.	Visit to algal cultivation pond/institute/industry	**2P**

BOT 511 MJ Plant Pathology
(2 Credits: 30 Lectures)

Credit 1: Plant diseases and pathogens		**15L**
1.	Concept of disease, classification	**1L**
2.	Rusts, smuts, mildews, wilt, blight, rot-causing fungi, symptoms, life cycles	**5L**
3.	Leaf spot, blight, wilt scabs, cankers, soft rot caused by bacteria, mosaic and ring spot causing viruses andyellowing, stunting and wilt causing nematodes	**3L**
4.	Plant disease epidemiology: Elements of an epidemic, patterns and comparison of epidemic development and forecasting plant disease epidemics	**2L**
5.	Pathogenesis: Infection, reproduction and dissemination	**2L**
6.	Pathogen effects on plant processes and growth	**1L**
7.	Emerging pathogens and effect on sustainable agriculture	**1L**
Credit 2: Host resistance, disease management and control of diseases		**15L**
1	Plant defenses: Non-host and host resistance	**1L**
2	Pre-existing and induceddefenses: Structural and chemical	**1L**
3	Defense signaling network: Immunity, Effectors, MAPK cascadeand PRPs	**3L**
4	Pathogenicity genes: effector molecules, role of enzymes and toxins in pathogenicity	**3L**

5	Diagnostic methods for detecting pathogens	**1L**
6	Control of disease using fungicides and other chemicals	**2L**
7	Biocontrol agents for controlling disease	**2L**
8	Disease control using biological and chemical activators of resistance	**2L**

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2. Plant Pathology and Plant Pathogens, John A. Lucas, WILEY
3. Fundamentals of Plant Pathology, R S Mehrotra, Ashok Aggarwal

BOT 518 MJP Practicals based on BOT 511 MJ (2 Credits: 15 Practicals)		
1	Study of different types of diseases in commercially important crops	**4P**
2	Isolation and culture of fungal pathogen from diseased plants	**2P**
3	Counting fungal spores using haemocytometer and artificial inoculation method	**2P**
4	Study of symptoms and disease scoring for any two fungal pathogens	**2P**
5	Observation of colonization pattern using fluorescent tagged vascular pathogen	**2P**
6	Isolation of DNA from infected plant tissue and assessment of pathogen load	**3P**
7	Molecular diagnostics of plant pathogen using PCR	**3P**
8	Control of pathogens using biological agents (*Pseudomonas* sp. /PGPRs/*Trichoderma* sp./*Serendipita indica*) and plant-based formulations	**4P**

BOT 512 MJ Medicinal mushroom cultivation (2 Credits: 30 Lectures)		
Credit 1: Introduction to medicinal mushrooms		**15L**
1	Medicinal mushrooms:Introduction, importance and health benefits Global scenario of trade and demand of medicinal mushrooms	**5L**
2	Overview of active principles in medicinal mushrooms	**3L**
3	Bioactive metabolites from *Cordyceps*, solid and liquid state fermentation and quality control of *Cordycepmilitaris*	**3L**
4	Isolation, identification and utilization of mushroom metabolites	**4L**
Credit 2: Cultivation of medicinal mushrooms		
1	Cultivation of Shiitake mushroom (*Lentinusedodes*), Lion's mane (*Hericiumerinaceus*)	**2L**
2	Cultivation, nutritional value and bioactive compounds in*Morchella* and Truffles	**3L**
3	Cultivation of *Ganoderma lucidum* on different substrates and its commercial products	**5L**
4	Turkey Tail (*Trametes versicolor*) farming	**2L**

5	Development of a mushroom cultivation unit, cost-benefit analysis, institutions involved in research and development of medicin mushrooms	**3L**

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BOT 519 MJP Practicals based on BOT 512 MJ
(2 Credits: 15 Practicals)

1	Identification of commercial medicinal mushrooms	**1P**
2	Isolation and *invitro* culture of medicinal mushrooms	**1P**
3	Cultivation practice for medicinal mushrooms (*Cordycep militaris*, Morchella/Truffles/*Trametesversicolor*)	**5P**
4	Cultivation of *Ganoderma lucidum*/*Lentinus edodes*/ *Hericium erinaceus*	**5P**
5	Study of various by-products of medicinal mushrooms available in the market	**3P**
6	Analysis of nutritional compounds in medicinal mushrooms	**3P**
7	Extraction and estimation of polysaccharides and terpenoids fro medicinal mushrooms	**2P**
8	Antioxidant activity (DPPH assay) of crude metabolites from mushroom extracts	**2P**
9	Study visit to a mushroom industry/fungal research laboratory	**2P**

BOT 513 MJ Post Harvest Technology (2 Credits: 30 Lectures)		
Credit 1: Post-harvest management of crops, fruits and vegetables		**15L**
1	Importance and scope of post-harvest management of commercially important crop plants	**3L**
2	Maturity indices and harvesting techniques for commercially importa crop plants, ornamentals, fruits and vegetables	**3L**
3	Pre-harvest practices, importance and their influence on post-harve losses	**2L**
4	Post-harvest biology: ripening, fruit softening, flavor, fragrance and senescence	**2L**
5	Post-harvest treatments to prevent losses during storage, increasir shelf-life: high and low temperature, chemicals, irradiation etc.	**3L**
6	Packaging methods and transportation	**1L**
7	Storage facilities and techniques	**1L**
Credit 2: Value addition to crop, fruits and vegetables		**15L**
1	Post-harvest Processing and preservation: Cleaning, sorting, and grading o produce, drying, dehydration of plant-based food	**3L**
2	Nutritive value of fresh and processed fruits	**2L**
3	Value addition in cereals, pulses, vegetables and fruits	**3L**
4	Post-harvest practices for spices and condiments	**2L**
5	Quality and safety standards of processed food products	**3L**
6	Marketing and trade	**2L**

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23. https://www.fda.gov/files/food/published/Food-Labeling-Guide-28PDF

BOT 520 MJP Practicals based on BOT 513 MJ
(2 Credits: 15 Practicals)

1	Effect of packaging containers on shelf life of fruits, vegetables and flowers	**2P**
2	Effect of low and high temperature on biochemical parameters determining shelf life and quality of fruits, vegetables and flowers	**4P**
3	Preparation of jam/jelly/ketchup	**2P**
4	Preparation of dried and dehydrated products	**2P**
5	Value added vegetables products	**2P**
6	Determination of pH, degree brix, nutritional parameters, TSS in fruit juice	**4P**
7	Visit to a food processing industry/institute	**2P**

BOT 514 MJ Plant Breeding (2 Credits: 30 Lectures)		
Credit 1: Principles of plant breeding		**15L**
1	Pre-and post-Mendelian concepts, plant breeding in India - major achievements and limitations, past, progress and future needs, green revolution, evergreen revolution	**2L**
2	Breeding objectives, genetic diversity in plants, centers of origin of crop plants, distribution and areas of diversity. Primary, secondary and tertiary gene pools. Importance of genetic diversity in crop improvement and its erosion	**3L**
3	Hybridization technique: Objectives, types, procedure, raising F1 generation, selfing, difficulties in hybridization	**4L**
4	Genetic basis of breeding cross pollinated crops: Genetic basis of self- incompatibility and male sterility and their use in hybrid seed production, genetic basis of inbreeding depression	**3L**
5	Crop varieties: Identification, release and notification of crop varieties, institutions involved in release of varieties	**3L**
Credit 2: Breeding Methods		
1	Breeding methods for self-pollinated crops: Mass selection, pure-line selection, pedigree selection, bulk method, backcross method	**5L**
2	Breeding methods for cross pollinated crops: Mass selection, progeny selection, recurrent selection	**5L**
3	Breeding methods for clonally propagated crops: Clonal selection, hybridization breeding for heterosis	**2L**
4	Mutations and polyploidy breeding: Mutagens: Physical and chemical mutagens, Mutant types, mutation breeding, mutant variety data (MVD)-IAEA, distant hybridization and polyploid breeding	**3L**

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10. Singh B. D. (2007). Plant Breeding. Kalyani Publishers. Ludhiana.

BOT 521 MJP Practicals based on BOT 514 MJ Plant Breeding (2 Credits: 15 Practicals)		
1	Self and cross hybridization in selected crop species (rice, maize, mustard, etc.)	**5P**
2	Floral biology in self and cross-pollinated species, pollen viability detection	**2P**
3	Study of quality traits in rice/cotton/wheat/soybean/mustard (any three)	**3P**
4	Use of colchicine for transduction of polyploidy in appropriate plant material	**3P**
5	Demonstration of hybrid variety, heterosis, and inbreeding depression	**2P**
6	Induction of mutations by physical/chemical mutagens and characterization of mutants	**4P**
7	Visits to plant breeding institutes within/nearby Pune	**2P**
BOT 515 MJ Industrial Botany (2 Credits: 30 Lectures)		
Credit 1: Plant-based industries		**15L**
1	Introduction, various plant resources, demand and supply	**2L**
2	Paper industry: Plant resources, pulp, paper manufacturing	**1L**
3	Plant fiber industry: Sources, commercial fibers, floss, cultivation, processing and utilization	**2L**
4	Rubber industry: Plant sources, cultivation, processing and utilization	**1L**
5	Natural dyes: Sources, cultivation, processing and utilization	**1L**
6	Gums and resins: Sources, cultivation, processing and utilization	**1L**
7	Timber industry: Commercial sources, silvicultural techniques, utilization	**1L**
8	Wood-based industry: Sources for musical instruments, toys, pencils, sports goods, etc., manufacturing methods and utilization	**2L**
9	Bamboo industry: Diversity, cultivation, harvesting, utilization and value addition	**2L**
10	Rattan: Sources, manufacturing of different products and uses	**1L**
11	Tannin industry: Commercial sources, manufacturing and utilization	**1L**
Credit 2: Commercial botany		**15L**
1	Edible oils: Sources, cultivation, processing and utilization	**2L**
2	Tree-borne oil-seeds (TBOs): Wild sources, Good Field Collection Practices (GFCPs), processing, value addition and uses	**2L**
3	Aromatic oils: Sources, commercially important oils, cultivation, processing and utilization	**2L**

4	Nutraceuticals and food supplements: Wild fruits and vegetables, tubers, millets: sources and commercial utilization	**2L**
5	Herbal medicine: Commercially important herbs, utilization and processing, industrial applications	**2L**
6	Botanical pesticides: Sources, processing and value addition	**1L**
7	Landscape gardening: Plant resources, availability, propagation and cultivation	**1L**
8	Exotic fruits: Sources, cultivation, processing and utilization	**1L**
9	Spices and condiments: Bioprospecting and cultivation	**1L**
10	Plant-based tourism: Agro, Eco, Health, Forest, etc.	**1L**

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BOT 522 MJP Practicals based on BOT 515 MJ Industrial Botany (2 Credits: 15 Practicals)		
1	Identification and characterization of industrially important medicinal plants	**2P**
2	Pulp preparation technique for paper industry	**1P**
3	Identification of fibre-yielding plants and extraction of fibres	**2P**
4	Identification of dye-yielding plants and their extraction methods	**2P**
5	Types of gums and resins, extraction and storage methods	**1P**
6	Bamboo propagation and cultivation	**2P**
7	Pharmacognostic studies of locally available medicinal plants in trade	**2P**
8	Distillation of essential oils from commercial aromatic plants	**2P**
9	Primary processing, packaging techniques and marketing of medicinal plants	**2P**
10	Identification of spices and condiments, their processing and storage techniques	**2P**
11	Establishment of concept garden by landscape technique	**4P**
12	Identification of plant sources as food supplements and nutraceuticals	**1P**
13	Methods for extraction of tannins	**1P**
14	Identification of woods and manufacturing of wood articles	**2P**
15	Preparation method for plant-based pesticide and testing	**2P**
16	Project proposal writing for financial assistance to establish plant-based unit for submission to bank/various organizations/NGOs, etc.	**2P**
17	Demonstration of accounting and marketing of plant-based products	**2P**
18	Industrial visit for demonstration of equipment, instruments and infrastructure required for plant-based industry	**2P**

BOT 516 MJ Cultivation and Utilization of Medicinal Plants (2 Credits: 30 Lectures)		
Credit 1: Cultivation and conservation		**15L**
1	Medicinal plants: aspects and prospects	**1L**
2	Medicinal plants used in various systems of traditional medicines, medicinal plants in demand, supply and sources	**3L**
3	Good Agricultural Practices (GAPs) of selected commercially important medicinal plants	**6L**
4	Good Field and Collection Practices (GFCP), primary processing	**2L**
5	Conservation and utilization of medicinal plant resources	**2L**
6	Markets in India, major traders, processers/pharma associations	**1L**
Credit 2: Start-up requirements		**15L**

1	Value addition: processing and product development (oils, powder, granules, herbal tea, nutraceuticals, cosmeceuticals, cosmetics, medicated water, tablets, health drinks, *Chyavanprash*, candy, etc.), innovative products	**4L**
2	Requirement for start-ups: infrastructure, machinery, manpower, testing laboratory, legal permissions	**2L**
3	Rules and regulations: GOI Ministries, FDA, FSSAI, Pollution Control Board, etc.	**2L**
4	Government Schemes and organizations involved in promotion of medicinal plants, Skill India Program, campaigns on medicinal plants, Ayush and MSME ministry	**2L**
5	Organic certification: Procedure and documentation	**2L**
6	Quality control: Various norms and tests	**2L**
7	Intellectual property right (IPR) issues	**2L**

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BOT 523 MJP Practicals based on BOT 516 MJ Cultivation and Utilization of Medicinal Plants		
1	Identification of major medicinal plants	**2P**

2	Identification of fresh and dried raw materials of medicinal plants in trade	**3P**
3	Nursery techniques for production of QPMs of medicinal plants, seed production	**2P**
4	GAPs for medicinal plants: Ashwagandha, Senna, Pippali	**3P**
5	Preparation of value-added products from amla, giloy, adulsa	**3P**
6	Post-harvest techniques for medicinal plants, processing and packaging: drying, grading, sorting and storage	**3P**
7	Extraction and identification of phytochemicals by Thin Layer Chromatography (TLC)	**2P**

BOT 541 MN Research Methodology
(2 Credits: 30 Lectures)

Credit 1: Foundation of research and execution		**15L**
1	Types of research, characteristics of scientific methods, understandin the language of research - concept, construct, definition, variables	**3L**
2	Importance of literature survey, sources of information, assessment of quality of journals and articles, effective literature studies approaches	**3L**
3	Formulation of research questions and hypothesis, hypothesis testing design of experiments	**3L**
4	Data analysis and application of statistical methods: sampling, data collection and documentation; analysis of qualitative and quantitative data- univariate, bivariate, and multivariate analysis. Outliers in the data. Statistical software	**5L**
Credit 2: Research ethics, safety measures, writing, and presentation skills		**15L**
1	Acts and biodiversity laws, permissions for plant collection, authentication of plant specimens, ethical issues, ethical and biosafet committees. Safely levels and permissions, plagiarism and self-plagiarisr Intellectual property rights- patent, designs, trade and copyright, ar patent law	**4L**
2	Lab safety measures: handling of chemicals, radioactive materials, instruments, disposals of chemicals and biological waste	**2L**
3	Dissertation: Different steps in the preparation - Layout, structure ar language of typical reports. Illustrations and tables, bibliograph footnotes, and acknowledgement. Preparation of effective presentatic	**6L**
4	Software for paper formatting, grammar checking, referencing, ar plagiarism detection	**3L**
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3. A Manual for Writers of Research Papers, Theses, and Dissertations, Ninth Edition. Chicago Style for Students and Researchers. Kate L. Turabian, Gregory G. Colomb, Joseph Bizup, Joseph M. Williams, Wayne C. Booth, William T. FitzGerald. University of Chicago Press.
4. A Professor's Guide to Writing Essays. The No-nonsense Plan for Better Writing. Second edition. Jacob Neumann.
5. Cite Right, Third Edition: A Quick Guide to Citation Styles--MLA, APA, Chicago, the Sciences, Professions, and More (Chicago Guides to Writing, Editing, and Publishing). Charles Lipson. University of Chicago Press.
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BOT 542 MNP Practicals based on BOT 541 MN Research Methodology
(2 Credits: 15 Practicals)

1	Formulation of hypothesis and its testing	**2P**
2	Analysis of qualitative and quantitative data sets	**3P**
3	Handling Systat/PAST3 for statistical analysis	**3P**
4	Making tables and graphs using Microsoft Excel	**3P**
5	Handling of Mendeley for referencing	**2P**
6	Manuscript formatting using Microsoft word	**2P**
7	Review writing, various databases	**3P**
8	Handling of Microsoft power point for scientific presentation	**2P**

SEMESTER II: CORE COURSES (Mandatory)		
BOT 551 MJ Taxonomy-III (Angiosperms) (2 Credits: 30 Lectures)		
Credit 1: Fundamentals of taxonomy		**15L**
1	Origin of angiosperms, cradle of angiosperms, abominable mystery, fossil angiosperms	**2L**
2	Morphological features used in identification of angiosperms	**3L**
3	Taxonomy: definition, aims, principles and importance. Taxonomic tools and literature: Flora, monograph, revisions, herbarium, botanic gardens, journals, websites. Organizations involved in angiosperm taxonomy	**2L**
4	Floristics: need and significance,history, methods, botanical explorations inIndia	**1L**
5	Global Taxonomy Initiatives:systematics agenda- 2000, systematics knowledge and value of biodiversity,biodiversity strategy and systematics agenda for 2020	**3L**
6	Systems of classification: brief history, artificial systems: Carl Linnaeus, Natural system: Bentham & Hooker Phylogenetic systems: Engler &Prantl, Cronquist, Takhtajan,	**4L**
Credit 2: Advances in taxonomy		
1	Overview of APG system of classification	**2L**
2	Families of angiosperms: Characteristic features, interrelationships and economic importance of following clades: ANA Grade: Nymphaeaceae Magnoliids: Magnoliaceae Monocots: Acorales-Poales Eudicots: Ranunculaceae and Core Eudicots: Amaranthaceae Superrosids: Crassulaceae Rosids-I: Fabaceae (Leguminosae) Rosids-II: Malvaceaeand Superasterids: Santalaceae Euasterids-I: Lamiaceae and Euasterids-II: Asteraceae	 **1L** **1L** **3L** **1L** **1L** **1L** **1L** **1L**
3	Endemism, hotspots, IUCN categories	**3L**

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17. Singh, Gurcharan. 2019. Plant Systematics: An Integrated Approach, Fourth Edition. CRC Press.7.
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21. Stuessy Tod F. 2002. Plant taxonomy. The systematic Evaluation of comparative data. Bishen Singh Mahendra Pal Singh, Dehra Dun.
22. Stuessy, Tod F., 2009. Plant taxonomy: the systematic evaluation of comparative data (2nd ed.). New York: Columbia University Press.
23. Takhtajan, A. 1986. Floristic Regions of the World. University of California Press.
24. Taylor, D. V. and L. J. Hickey 1997. Flowering plants: Origin, evolution and phylogeny CBS Publishers a Distributors New Delhi.
25. Walter S. Judd, Christopher S. Campbell, Elizabeth A. Kellogg, Peter F. Stevens and Michael J. Donoghue. 2007. Plant Systematics: A Phylogenetic Approach, Third Edition. Sinauer Associates, Inc., Publishers, Sunderland, USA.

BOT 552 MJ Plant Development-I (2 Credits: 30 Lectures)		
Credit 1: Basic Concepts in Plant Development		**15L**
1	Basic processes in plant development a. Competence, determination, commitment, specification, induction, differentiation, dedifferentiation and redifferentiation b. Morphogenetic gradients, cell fate and cell lineages c. Polarity and symmetry d. Juvenility and transition to adult phase	**4L**
2	Development of epidermal structures: trichomes and stomata	**2L**
3	Development of vascular elements: differentiation of xylem and phloem	**2L**
4	Secondary growth: cambium, gross structure of wood	**2L**
5	Development of secretory tissues: nectaries, laticifers and resin ducts	**2L**
6	Transition from vegetative to reproductive phase: induction, morphological and biochemical changes in shoot apex and floral meristems	**3L**
Credit 2: Vegetative Development		**15L**
1	Meristem types and activities of meristems. Organization of shoot ar root apical meristems. Regulation of meristem size, lateral organ initiation from root and shoot meristems	**3L**
2	Leaf development, plastochron and phyllotaxy	**2L**
3	Molecular genetics of rootdevelopment Molecular genetics of shoot development Molecular genetics of leaf development	**3L** **4L** **3L**

Suggested References

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2. Bhojwani S. S., Dantu P. K. and Bhatnagar S. P. (2014). The Embryology of Angiosperms. (6th Edition) Vikas Pub. House. Paperback edition.
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13. Lyndon R.F. (1990) Plant Development: The Cellular Basis. (Topics in Plant Physiology, Vol. 3) Springer Publications.
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17. Wareing P. F. and Philips I. D. J. (1981) Growth and Differentiation in plants. Pergamon Press
18. Wolpert L., Tickle C. and Arias A. M. (2015) Principles of Development. (5th Edition) Oxford University Press.

BOT 553 MJ Plant Ecology
(2 Credits: 30 Lectures)

Credit 1: Population Ecology		**15L**
1	Concept and scope of Ecology	**1L**
2	Autecology,SynecologyandMacroecology	**1L**
3	Ecological Models:Concepts, classification, model building and tools	**1L**
4	Molecular Ecology: Concept, tools,applications	**2L**
5	Population Ecology: Characteristics of population	**1L**
6	Ecological limits and size of the population	**2L**
7	Life history strategies and evolution, CSR triangle	**2L**
8	Metapopulation: Concept, types and dynamics, theory of island biogeography	**3L**
9	Extinction events, population viability analysis	**2L**
Credit 2: Community Ecology		**15L**
1	Concept, niche, ecotone and edge effect, evolution and coevolution	**3L**
2	Plant-plant interactions:types, epiphytic, parasitism and allelopathy	**3L**
3	Intra- and inter-specific interactions: competition, predation, herbivory	**2L**
4	Community structure, genetic and species diversity	**2L**
5	Qualitative and quantitative analysis of community	**2L**
6	Physiognomy and phenology of community	**1L**
7	Plant community in changing environment:disturbance, climate change and invasion	**2L**

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1. Begon, M., Townsend, C. R. and Harper, J. L. (2005). *Ecology: From individuals to Ecosystems* 4th edition, Wiley-Blackwell.
2. Odum, E. P. (2007) *Fundamentals of Ecology*, 5th edition, Thomson books.
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9. Mittelbach, G. G., & McGill, B. J. (2019). *Community Ecology*. Oxford University Press.
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16.Hasanuzzaman, M., Fujita, M., Oku, H, andTofazzal Islam, M. (2019). *Plant Tolerance to Environmental Stress*. CRC Press
17. Dighton, J. (2018). *Fungi in Ecosystem Processes*. CRC Press
18. Cronk, J. K. and Siobhan Fennessy, M. (2001). *Wetland Plants*. CRC Press
19. Lemon, E. R. (2019). *CO2 and Plants*. The Response of Plants to Rising Levels of Atmospheric Carbon Dioxide. CRC Press
20. Davet, P. (2004). Microbial Ecology of Soil and Plant Growth. CRC Press
21. Schulze, E.D., Beck, E. and Muller-Hohenstein, K. (2002). Plant Ecology. Springer

BOT 554 MJ Cell Biology
(2 Credits: 30 Lectures)

Credit 1: Cell organelles, cell cycle and senescence		**15L**
1	Cell wall: Biogenesis, ultra-structure, primary and secondary wall, cell expansion and elongation, functions	**2L**
2	Cell membranes:molecular organization, transport of ions across membranes, membrane transport proteins, structure and role of plasmodesmata	**2L**
3	Cell organelles: structure and function of vacuole, ER, mitochondria, chloroplast, Golgi complex, nucleus	**4L**
4	Cell cycle:phases of cell cycle, functional importance, check points, molecular events and regulation of cell cycle	**3L**
5	Senescence, programmed cell death, apoptosis, receptors and other proteins involved in selective autophagy, intracellular homeostasis	**4L**
Credit 2: Signal transduction		
1	Signal transduction: Types of receptors, G-proteins and G-protein coupled receptors	**4L**
2	Phospholipid signaling, Ca^{2+} calmodulin cascade, diversity in protein kinases and phosphatases, secondary messengers, regulation of signaling pathways	**6L**
3	Specific signaling mechanisms: biotic and abiotic stress, ABA induced stomatal closure	**3L**
4	Nuclear: organelle signaling during plastid development	**2L**

BOT 555 MJ Molecular Biology-1 (2 Credits: 30 Lectures)		
Credit 1: DNA and RNA		**15L**
1	DNA structure: types of base pairing, unusual structures, topology	**2L**
2	Melting and reassociation of DNA, Cot curves and kinetic complexity of DNA. Organization of genomes, repetitive and unique sequences, C value paradox, number of genes, rot curves and gene expression, gene duplication and divergence	**3L**
3	Packaging of genomes in nuclei, structure of chromatin, nucleosome positioning,histone modifications,chromosome organization, centromeres, telomeres	**3L**
4	Initiation, elongation and termination of DNA replication, molecular machinery of DNA replication in prokaryotes and eukaryotes	**3L**
5	RNA structure: modified bases, pairing, secondary structure	**1L**
6	Transcription units, RNA polymerases, initiation, elongation and termination of transcription in prokaryotes and eukaryotes	**3L**
Credit 2: Protein synthesis and translocation	**15L**	
1	Protein synthesis: tRNA charging, ribosomal organization. Initiation, elongation and termination of protein synthesis in prokaryotes and eukaryotes,proof reading	**5L**
2	Post-translational processing of proteins, protein modifications. Chaperones and protein folding	**3L**
3	Proteases,ubiquitination and degradation of proteins by proteasomes	**2L**
4	Protein targeting in cell organelles and secretory proteins	**3L**
5	Seed-storage proteins in cereals and legumes	**2L**

Reference books

1. Genes IX– Benjamin Lewin, Jones and Bartlett, 2008
2. Genes X– Benjamin Lewin, Jones and Bartlett, 2011
3. Molecular Biology of the Cell – Alberts, B, Bray, D, Raff, M, Roberts, K and Watson JD, Garland Publishers, 1999
4. Principles of Biochemistry – Lehninger, W.H. Freeman and Company, 2005

BOT 556 MJP Practicals on BOT 551, 552, 553 MJ		
Practicals based on BOT MJ 551 Taxonomy III (Angiosperms)		
1	Identification and study of plant species using taxonomic tools	**2P**
2	Preparation of herbarium specimens, documentation and digitization (physical vs. virtual)	**2P**
3	Studies on the following Classes as per Bentham and Hooker's system of classification at least one family from each group/class/order and preparation of artificial keys for identification of any two unknown specimens:	

	Dicotyledons: a. Polypetalae: Thalamiflorae, Disciflorae, Calyciflorae b. Gamopetalae: Inferae, Heteromerae, Bicarpellatae c. Monochlamydae: Curvembryae, Multiovulateaquaticae, Multiovulateterrestris, Microembryae, Daphniales, Achlamydosporae, Unisexuales, *Ordines anomali*. **Monocotyledones:** a. Microspermae b. Epigynae c. Coronariae d. Calycinae e. Nudiflorae f.Apocarrae g. Glumaceae	**7P** **4P**
4	Identification of economically important plants	**3P**
5	*Ex-situ* conservation methods of biodiversity – through seed, vegetative methods. (any one plant species per technique)	**2P**
Practicals based on BOT MJ 552 Plant Development-I		**5P**
1	Isolation of vegetative and reproductive apical meristems and their comparison	**1P**
2	Comparative studies on stomatal types in dicots and monocots	**1P**
3	Observation of epidermal (trichomes, glands and lenticels) and secretory (nectaries and laticifers) structures	**1P**
4	Histochemical comparison of vegetative and reproductive shoot apex	**2P**
Practicals based on BOT MJ 553 Plant Ecology		
1	Determination of minimum size of sampling unit for studying specific plant community	**2P**
2	Determining frequency, density, abundance and Importance Value Index (IVI) of the species in a plant community	**3P**
3	Calculating species richness, similarity, diversity indices, cluster analysis and coordination in different plant communities	**2P**
4	Analyses and interpretation of plant population data	**1P**
5	Effect of leaf leachates on seed germination/saplings	**2P**
6	Isolation and observation of root-associated microbes	**2P**
7	Study of stratification and physiognomy of a plant community	**1P**
8	Determination of similarity and association index	**1P**
BOT MJP 557 Practicals based on BOT 554 and 555 MJ		
Practicals based on BOT MJ 604 Cell Biology		
1	Isolation of chloroplast fraction for: a. Studying Hill reaction b. Measuring size and number of broken and intact chloroplast	2P
2	Cytochemical studies of special cell types: guard cells, senescent cells, bundle sheath cells, meristematic cells, laticiferous cells, glandular cells	**3P**
3	To induce and study senescence in leaf samples	**2P**
4	To induce plasmolysis and observe plasmodesmatal connections in plant cells	**1P**

Practicals based on BOT MJ 605 Molecular Biology		**5P**
1	Isolation and quantification of plasmid DNA	**2P**
2	Electrophoretic separation of plasmid isoforms	**1P**
3	Isolation and quantification of plant genomic DNA	**2P**
4	Effect of temperature and alkali on absorbance of DNA	**1P**
5	Isolation of seed-storage proteins from leguminous seeds and quantitation of each fraction	**2P**
6	SDS-PAGE-based separation of globulins and relative molecular weight determination	**3P**
SEMESTER II: ELECTIVE COURSES		
BOT 560 MJ Plant Tissue Culture (2 Credits: 30 Lectures)		
Credit 1: Fundamentals of plant tissue culture (PTC)		**15L**
1	History and conceptsunderlying PTC	**2L**
2	Laboratory set up: Sterility, Growth media, Nutrients and Plant Growth Regulators	**2L**
3	Micropropagation: selection of explants, media, growth regulators, stages and case studies	**5L**
4	Callus and cell suspension cultures: selection of explants, media, growth regulators, growth kinetics, bioreactors and case studies	**6L**
Credit 2: Applied aspects of PTC		**15L**
1	Somaclonal variation, androgenesis, germplasm conservation and cryopreservation	**5L**
2	Somatic embryogenesis and synthetic seed production	**2L**
3	Protoplast isolation and culture,somatic hybridization	**2L**
4	Plant production: scaling up, cost and budget-related aspects	**3L**
5	Export potential of PTC-based products and quality control	**3L**

Suggested References

1. Bajaj Y. P. S. Ed. (1988) Biotechnology in Agriculture and Forestry – vol. 4, Springer-Verlag, Berlin, Heidelberg, New York, Tokyo.
2. Chandra S., Lata H. and Varma A. (2013) Biotechnology for Medicinal Plants. Micropropagation and Improvement. Springer-Verlag, Berlin, Heidelberg.
3. Charlwood B. V. and Rhodes M. V. Ed. (1999) Secondary products from plant tissue culture. Clarendon Press, Oxford.
4. Cseke L. J., Kirakosyan A., Kaufman P. B., Warber S., Duke J. A. and Brielman H. L. (2006) Natural Products from Plants. 2nd Edition, CRC Press, Taylor & Francis Group.

5. Das H. K. Ed. (2007) Textbook of Biotechnology. 3rd Edition. Wiley India (P) Ltd.
6. Fu T.-J., Singh G. and Curtis W. R. (2000) Plant Cell and Tissue Culture for the Production of Food Ingredients. Springer International Edition. Springer (India) Pvt. Ltd., New Delhi.
7. Jain S. M. and Saxena P. K. (2009) Protocols for in vitro Cultures and Secondary Metabolite Analysis of Aromatic and Medicinal Plants. Humana Press.
8. Kurz W.G.W. Ed. (1989) Primary and Secondary Metabolism of Plant and Cell Cultures, Springer Verlag, Berlin.
9. Morris, A.H. et al., Eds (1986) Secondary Metabolism in Plant Cell Cultures, Cambridge Univ. Press, Cambridge, U.K.
10. Trigiano R. N. and Gray D. J. (1999) Plant Tissue Culture Concepts and Laboratory Exercises. 2nd Edition. CRC Press, Boca Raton, New York.
11. Verpoorte R. and Alferman H. W. (Editors) (2003) Metabolic engineering of plant secondary metabolites. Kluwar Academic Publishing.

BOT 567 MJP Practicals Based on BOT 560 MJ Plant Tissue Culture (2 Credits: 15 Practicals)		
1	Preparation of nutrient media, sterilization of glassware and media, maintenance of aseptic conditions	**2P**
2	Micropropagation of *Withania* sp./Gerbera/*Gladiolus*/Carnation: explant selection, surface sterilization, media preparation, inoculation, incubation and sub-culturing	**5P**
3	Callus culture of sugar beet: explant selection, surface sterilization, media preparation, inoculation, incubation and sub-culturing	**4P**
4	Extraction and separation of pigments from beet root callus	**3P**
5	Standardization of a low cost micropropagation protocol	**4P**

BOT 561 MJ Plant-Organism Interaction (2 Credits: 30 Lectures)		
Credit 1: Plants interacting with macro-organisms		**15L**
1	Beneficial interaction: Plant-pollinator interaction, pollination mutualism (obligate and facultative). Interrelationship between floral morphology, chemistry and pollination	**3L**
2	Different insect herbivores and their feeding patterns, plant defense strategies, growth-defense trade-offs. Plant-mollusks interaction	**4L**
3	Plant defense mechanisms against herbivores: defense signaling, defense moleculesand cross-talk,tritrophic interactions	**5L**
4	Below ground interaction: Plant-nematode interaction- recognition, signaling, mechanism, defense molecules against nematodes	**3L**

Credit 2: Plants interacting with micro-organisms		**15L**
1	Lichens: types, symbiotic partners, relationship and mutualism	**2L**
2	Endophytes: types, association, role in plant growth promotion and alleviation of biotic and abiotic stress	**4L**
3	Mycorrhizal symbiosis: ecto- and endo mycorrhizae, mycorrhizal induced resistance, role in plant growth promotion and alleviation of biotic and abiotic stress, tritrophic interactions	**5L**
4	Nodulating bacteria: *Rhizobium*, nod factors, mechanism of nitrogen fixation	**1L**
5	Nematophagous fungi: diversity, physical and biochemical interactions between nematodes and fungi, biological control	**3L**

Suggested References

1. Hormonal Cross-Talk, Plant Defense and Development. Plant Biology, Sustainability and Climate Change **(**2023)- Edited by: AzamalHusen and Wenying Zhang.
2. Plant-Microbe Interaction - Recent Advances in Molecular and Biochemical Approaches (2023) Volume 2: Agricultural Aspects of Microbiome Leading to Plant Defence.Edited by: Prashant Swapnil, Mukesh Meena, ... Andleeb Zehra.
3. Variable Plants and Herbivores in Natural and Managed Systems (1983) Edited by: Robert F. Denno and Mark S. McClure
4. Herbivores: Their Interactions with Secondary Plant Metabolites **(**1991**)** Volume I: The Chemical Participants**.** Second Edition**.** Edited by: Gerald A. Rosenthal and May R. Berenbaum.
5. Herbivores: Their Interactions with Secondary Plant Metabolites (1992). Volume II: Ecological and Evolutionary Processes. Second Edition. Edited by: Gerald A. Rosenthal and May R. Berenbaum.
6. Fungal endophytes in plants (2018). Edited by Gary A. Strobel.
7. Microbial endophytes (2020) Functional Biology and Applications. eBook ISBN:9780128226650. Edited by: Ajay Kumar. Radhakrishnan A.K.
8. Mycorrhizal Symbiosis (2008). 3rd edition. Sally Smith and David Read. eBook ISBN:9780080559346.
9. Arbuscular Mycorrhizae Interactions in Plants, Rhizosphere, and Soils (2002). Edited By: AK Sharma and BN Johri
10. Molecular Mycorrhizal Symbiosis (2016). Online ISBN: 9781118951446 |DOI:10.1002/9781118951446. Edited by: Francis Martin

BOT 568 MJP Practicals based on BOT 561 MJ Plant-Organism Interaction (2 Credits: 15 Practicals)		
1	Study of different feeding guilds	**1P**
2	Effect of herbivory on plant photosynthesis and growth	**2P**
3	Estimation of levels of plant defense molecules before and after herbivory	**3P**
4	Effect of host and non-host plants on herbivore performances	**3P**
5	Estimation of flavonoids in nematode infested plants	**2P**
6	Effect of plant defense metabolites on insect growth	**3P**
7	Estimation of green leaf volatiles (GLVs) upon herbivory by GCMS	**3P**
8	Isolation of Arbuscular Mycorrhizal Fungi (AMF) from rhizosphere and determination of percent colonization in plant roots	**2P**
9	*In vivo* culture, maintenance of AMF and its effect on plant growth	**3P**
10	Observation and documentation of various lichen forms in nearby forest area	**2P**
11	Isolation, *in vitro* culture and testing of nitrogen fixing ability of nodulating and non-nodulating bacteria	**2P**
12	Isolation and observation of nematodes from rhizospheric soil/root galls	**2P**
BOT 562 MJ Plant Immunity (2 Credits: 30 Lectures)		
Credit 1: Pathogen perception, defense signaling and resistance		**15L**
1	Overview of host pathogen interaction, plant pathogens, pests and plant diseases	**1L**
2	Host and non-host defenses: Pre-existing and induced structural and chemical defenses	**2L**
3	Active defense: pathogen recognition (PAMPs and DAMPs), plant receptors (PRRs and NLRs), PTI, ETI, resistosomes	**3L**

4	Signal transduction pathways activated during plant resistance to pathogens, role of MAPK signalling, role of SA and JA signalling	**4L**
5	Transcriptional reprogramming in plant defense and role of transcription factors	**3L**
6	Role of pathogenesis related proteins (PRPs) and specialized secondary metabolites in defense	**2L**
Credit 2: Priming, induced resistance and small RNAs		**15L**
1	Concept of priming, induced resistance: SAR and ISR, chemical induced resistance	**4L**
2	Phytohormone cross talk in SAR and ISR	**2L**
3	Epigenetic control of plant defense mechanism	**2L**
4	Cross kingdom role of small RNAs in interaction, HIGH and SIGS	**4L**
5	Genetic engineering forplant disease resistance	**3L**

Suggested References

1. Agrios Plant Pathology, 6th Edition, Editor Richard Oliver

2. Plant Pathology and Plant Pathogens, John A. Lucas, WILEY

3. Biochemistry and Molecular Biology of Plants, 2nd Edition, Bob B. Buchanan, (Editor), Wilhelm Gruissem (Editor), Russell L. Jones (Editor), WILEY

BOT 569 MJP Practicals based on BOT 562 MJ Plant Immunity		
1	Culture and maintenance of fungal pathogens	**2P**
2	Artificial inoculation of fungal pathogen and disease scoring	**3P**
3	Detection of H_2O_2 accumulation in infected plant tissue by DAB staining	**1P**
4	Detection of callose deposition in infected plant tissue	**1P**
5	Time course evaluation of antioxidative enzyme activity during fungal infection	**3P**
6	Expression analyses of defense genes in infected plant tissue	**4P**

BOT 563 MJ Organic Farming (2 Credits: 30 Lectures)		
Credit 1: Fundamentals of organic farming		**15L**
1	Historical overview: Importance, principles and advantages of organic farming	**2L**
2	Organic farming practices: Crop rotation, diversification, composting, vermicomposting, green manuring, biofertilizers, microbial consortia, IPM,IKS in organic farming, biodynamic farming, permaculture, community supported agriculture, biomass utilization	**5L**
3	Organic farming for specific crops: Cereals, pulses, millets, vegetables, spices, fruits, medicinal and aromatic plants	**5L**
4	Plant resources required forbee keeping (apiculture) and sericulture	**2L**
Credit 2: Marketing and certification, Government policies15L		
1	Social aspects of organic farming, organic farming certification process, organic market trends in India, marketing organic produces, organizations and associations involved	**5L**
2	Government policies,national programmes and support for organic farming in India, incentives and subsidies, government schemes	**5L**
3	Challenges and future of organic farming, solutions and innovations, future prospects and opportunities, success stories/case studies, organic producer companies/ farmers/ NGOs	**5L**

Suggested References

1. Awasthi, L. P. (Ed.). (2021). Biopesticides in organic farming: recent advances.
2. Barbieri, P., Starck, T., Voisin, A. S., &Nesme, T. (2023). Biological nitrogen fixation of legumes crops under organic farming as driven by cropping management: A review. *Agricultural Systems*, *205*, 103579.
3. Biswas, S., Ali, M. N., Goswami, R., & Chakraborty, S. (2014). Soil health sustainability and organic farming: A review. *Journal of Food Agriculture and Environment*, *12*(3-4), 237-243.
4. Chandrashekar, H. M. (2010). Changing scenario of organic farming in India: An overview.
5. Das, S., Chatterjee, A., & Pal, T. K. (2020). Organic farming in India: a vision towards a healthy nation. *Food Quality and Safety*, *4*(2), 69-76.
6. Das, S., Chatterjee, A., & Pal, T. K. (2020). Organic farming in India: a vision towards a healthy nation. *Food Quality and Safety*, *4*(2), 69-76.
7. Dhiman, V. (2020). Organic farming for sustainable environment: Review of existed policies and suggestions for improvement. *International Journal of Research and Review*, *7*(2), 22-31.

8. Joachim, S. (2006). Review of history and recent development of organic farming worldwide. *Agricultural sciences in China*, *5*(3), 169-178.
9. Lakner, S., &Breustedt, G. (2017). Efficiency analysis of organic farming systems a review of concepts, topics, results and conclusions. *German Journal of Agricultural Economics*, *66*(2), 85-108.
10. Lammerts van Bueren, E. T., Jones, S. S., Tamm, L., Murphy, K. M., Myers, J. R., Leifert, C., & Messmer, M. M. (2011). The need to breed crop varieties suitable for organic farming, using wheat, tomato and broccoli as examples: A review. *NJAS: Wageningen Journal of Life Sciences*, *58*(3-4), 193-205.
11. Lund, V., &Algers, B. (2003). Research on animal health and welfare in organic farming—a literature review. *Livestock Production Science*, *80*(1-2), 55-68.
12. Lynch, D. H., MacRae, R., & Martin, R. C. (2011). The carbon and global warming potential impacts of organic farming: does it have a significant role in an energy constrained world?. *Sustainability*, *3*(2), 322-362.
13. Mukherjee, K., Konar, A., & Ghosh, P. (2022). Organic farming in India: A brief review. *International Journal of Research in Agronomy*, *5*(2), 113-118.
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BOT 570 MJP Practicals based on BOT 563 MJ Organic Farming
(2 Credits: 15 Practicals)

1	Designing and planning of organic farm and maintenance of field record	**1P**
2	Preparation of vermicompost/green manure/organic manure and analyses of N, P, K	**2P**
3	Preparation of bacterial biofertilizer and testing its *in vitro* plant growth promoting activity	**3P**

4	Identification of pests and diseases and their biocontrol using biopesticides	**2P**
5	Preparation of *Panchgavya*, *Beejamrut* and *Jeevamrut*and its effect on plant growth promotion	**2P**
6	Physico-chemical analyses of soil	**2P**
7	Procedure for documentation and certification of organic products	**1P**
8	Visit to a biofertilizer manufacturing unit, organic farm and market	**2P**
BOT 564 MJ Carbon Credit and Environment Impact Assessment (2 Credits: 30 Lectures)		
Credit 1: Carbon and green credit		**15L**
1	Concept and significance, green credit importance, greenhouse gases, global warming andnet zero concept	**2L**
2	Carbon credit initiative, Paris climate agreement, Glasgow COP26 climate change summit	**2L**
3	Carbon trading credit and carbon market,status in developed and developing countries	**2L**
4	Carbon trading emissions under Kyoto protocol, CDM, emission trading in India	**2L**
5	Plants and mitigation of pollution	**1L**
6	Green belt and its significance	**1L**
7	Modelling of greenbelt and plantation design	**1L**
8	Nursery techniques and plantation methods	**1L**
9	Acts and regulations related to carbon credit and green credit, green climate fund	**1L**
10	Preparation of project proposal, procedure for tendering related to carbon credit, central pollution control board, various ministries, their role, activities and schemes	**2L**
11	Organizations, Institutes, NGOs working in the field of carbon credit	**1L**
Credit 2: Environmental Impact Assessment		**15L**
1	Concept, impact analysis, assessment and impact statement	**2L**
2	EIA and its importance in project planning process	**1L**

3	Contents of EIA: project description, anticipated environmental impacts and mitigation measures	**2L**
4	Environmental monitoring programme, project benefits, environmental cost benefit analysis	**2L**
5	Environment attributes: air, water, noise, land and soil	**2L**
6	Monitoring of physical environmental parameters, collection and interpretation of baseline data for various environmental attributes	**2L**
7	Application of various models for prediction of impact on air environment, water environment, noise environment and land	**2L**
8	EIA notification September 2006 and amendments: categorization of projects, procedure for environmental clearance, public participation in environmental decision-making process	**2L**
BOT 571 MJP Practicals based on BOT 564 MJ Carbon Credit and Environment Impact Assessment (2 Credits: 15 Practicals)		
1	Estimation of carbon credit by non-destructive method for determining biomass/carbon assimilation of trees	**2P**
2	Estimation of water and waste management-based carbon credit of campus/society/industry	**2P**
3	Estimation of carbon credit based on air pollution reduction	**1P**
4	Assessment of carbon foot-print of Botanic garden/society/industry	**2P**
5	Demonstration of silviculture practices for green belt development	**3P**
6	Collection and interpretation of meteorological data for baseline study of EIA	**2P**
7	Collection and interpretation of air and noise pollution data	**1P**
9	Assessment of physico-chemical properties of surface and ground water	**2P**
10	Assessment and interpretation of soil quality baseline data	**1P**
11	Collection and interpretation of baseline ecological and biodiversity data	**1P**
12	Case studies on EIA for industries and infrastructure projects	**2P**

BOT 565 Millet-based Nutraceuticals (2 Credits: 30 Lectures)		
Credit1: Introduction to millets		
1	Classification: major, minor, pseudo-millets	**2L**
2	Global scenario of millet cultivation, millet producing states in India, millet map of India, Indian Knowledge System (IKS): Description of medicinal and health benefits of millets in Ayurvedic texts (balancing *doshas*)	**4L**
3	Cultivation practices of millets in India: broadcasting, transplanting, inter-cropping etc., major pests and pathogens, control measures	**2L**
4	Nutritional parameters (dietary fiber, proteins, carbohydrates, lipids, vitamins, micronutrients etc.) of different millets and their comparison with other cereals	**2L**
5	Millets in the Indian rural and urban diet, consumption preferences, role of millets in reducing nutrient deficiency	**2L**
6	Agronomic trait improvement in millets, nutrigenomics and nutrigenetics	**3L**
Credit 2: Nutraceutical value of millets		
1	Introduction to nutraceuticals, formulations, plant-based nutraceuticals	**3L**
2	Overview of polyphenol, flavonoid, phytic acid, carotenoid, tocopherol, phytosterol, arabinoxylan content in millets	**3L**
3	Health benefits of millets: strengthening bones, positive effect on nervous system, maintaining cardiac health, managing type-II diabetes, lowering cholesterol, promoting immunity etc.	**3L**
4	Anti-oxidant and anti-aging properties of finger millet	**1L**
5	Processing of millets: dehusking/decortication, milling, soaking, germination, malting, fermentation, cooking, roasting etc.	**3L**
6	Start-up opportunities: manufacturing value-added products, branding, product development and marketing	**2L**

Suggested References

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BOT 572 MJP Practicals on BOT 565 Millet-based Nutraceuticals (2 Credits: 15 Practicals)

1	Estimation and comparison of total carbohydrates from finger millet and little millet	**2P**
2	Estimation of total nitrogen from finger millet by the Kjeldahl method	**2P**
3	Estimation and comparison of total lipid content in different millets	**2P**
4	Estimation of reducing sugars, total fibre and ash content in little millet	**2P**
5	Estimation of Fe, Ca, Mg in red and white landraces of finger millet	**2P**
6	Processing of millets for manufacturing value-added products (extruded snacks, noodles, flakes etc.) and assessment of their sensory attributes	**3P**
8	Malting of finger millet grains to prepare ‘ragi-malt’ and its nutritional analyses	**2P**
9	Visit to a millet-based local industry/minor millet cultivation in a tribal area	**2P**

BOT 566 MJ Aromatic Plants (2 Credits: 30 Lectures)		
Credit 1: Aspects and Prospects		
1	Aromatic Plants: Introduction, Diversity, Aspects and Prospects	**2L**
2	Commercial names, Sources, Major Volatile Compounds	**2L**
3	Aromatic Herbs in Food	**1L**
4	Bioactive Compounds, Processing, and Applications	**2L**
5	Properties of bioactive compounds, recovery and applications	**1L**
6	Spices and Condiments- Diversity, Cultivation and Utilization	**2L**
7	Application of essential oil- Aromatherapy, Aromatics, Perfume, Room Freshener, Deodorants, Cosmaceuticals, medicines, mosquito repellent, etc	**4L**
8	Aroma mission, Government schemes, Processing unit	**1L**
Credit 2: Cultivation, processing and marketing		
1	Agro-techniques for commercially important aromatic crops found in various agro climatic regions (comparative account)	**5L**
2	High yielding varieties and their characteristics	**1L**
3	Processing, extraction technologies, green extraction technologies, encapsulation of recovered bioactives	**5L**
4	Aromatic trade: documentation, sources, markets	**1L**
5	Establishment of processing unit: procedure, cost and requirements	**1L**
6	Packaging, Trademark, Value addition, Marketing	**2L**

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BOT 573 MJP Practicals based on BOT 566 MJ Aromatic Plants
(2 Credits: 15 Practicals)

1	Identification of aromatic plants including spices	**2P**
2	Identification of raw material and various value-added products	**2P**
3	Nursery techniques for propagation of citronella, vetiver, palmarosa and geranium	**2P**
4	Agrotechniques of commercially important aroma crops	**5P**
5	Lab and commercial scale extraction methods of essential oils	**3P**
6	GC-MS analyses of lemon grass/mint/geranium/vetiver	**3P**
7	Preparation of value-added products such as perfume, room freshener, deodorants, mosquito-repellent	**4P**
8	Project proposal writing, bank loan procedure	**2P**
9	Exposure to trading, wholesale and retail market	**2P**
10	Visits to processing industry/field	**4P**

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BOT 581 OJT/FP	**On Job Training (OJT)/Field Project/FP**	**4C**

COURSE STRUCTURE FOR M. Sc. BOTANY PART II (SEMESTER III AND IV)

Course Code	Course Name	Credits
Credit Framework for Semester-III		
Major Core [10 (T) + 4 (P)]		
BOT-601-MJ	Molecular Biology-II	2
BOT-602-MJ	Tools and Techniques in Botany-I	2
BOT-603-MJ	Climate change and plants	2
BOT-604-MJ	Plant genetic engineering	2
BOT-605-MJ	Plant Development-II	2
BOT-606-MJP	Practicals based on MB-II & TTB-I	2
BOT-607-MJP	Practicals based on climate change and plants, plant genetic engineering & plant development - II	2
	Total Major Core Credits	**14**
Major Elective (any one)		
BOT-610-MJ(A)	Advanced Phycology- I	2
BOT-610-MJ(B)	Advanced Mycology-I	
BOT-610-MJ(C)	Angiosperms systematics - I	
BOT-610-MJ(D)	Plant Ecology-I	
BOT-610-MJ(E)	Advanced Plant Physiology-I	
BOT-610-MJ(F)	Pharmacognosy – I	
BOT-610-MJ(G)	Advanced Plant Genetics and Breeding-I	
BOT-610-MJ(H)	Plant Biotechnology- I	
BOT-611-MJP(A)	Practicals based on BOT-610-MJ(A) Advanced phycology - I	2
BOT-611-MJP(B)	Practicals based on BOT-610-MJ(B) Advanced Mycology-I	
BOT-611-MJP(C)	Practicals based on BOT-610-MJ(C) Angiosperms systematics -I	
BOT-611-MJP(D)	Practicals based on BOT-610-MJ(D) Plant Ecology-I	
BOT-611-MJP(E)	Practicals based on BOT-610-MJ(E) Advanced Plant Physiology -I	
BOT-611-MJP(F)	Practicals based on BOT-610-MJ(F) Pharmacognosy-I	
BOT-611-MJP(G)	Practicals based on BOT-610-MJ(G) Advanced Plant Genetics and Breeding- I	
BOT-611-MJP(H)	Practicals based on BOT-610-MJ(H) Plant Biotechnology- I	
	Total Major Elective Credits	4
BOT-631-RP	Research Project	4
	Total Credits for Semester-III	22

Course Code	Course Name	Credits
Credit Framework for Semester-IV		
Major Core [8 (T) + 4 (P)]		
BOT-651-MJ	Bioinformatics and Biostatistics	2
BOT-652-MJ	Plant Evolution	2
BOT-653-MJ	Tools and Techniques in Botany-II	2
BOT-654-MJ	Biodiversity, conservation & utilization	2
BOT-655-MJP	Practicals based on Bioinformatics and Biostatistics and Plant Evolution	2
BOT-656-MJP	Practicals based on TTB-II and Biodiversity, conservation & utilization	2
	Total Major Core Credits	**12**
Major Elective (any one)		
BOT-660-MJ(A)	Advanced Phycology- II	2
BOT-660-MJ(B)	Advanced Mycology-II	
BOT-660-MJ(C)	Angiosperms systematics - II	
BOT-660-MJ(D)	Plant Ecology-II	
BOT-660-MJ(E)	Advanced Plant Physiology-II	
BOT-660-MJ(F)	Pharmacognosy – II	
BOT-660-MJ(G)	Advanced Plant Genetics and Breeding-II	
BOT-660-MJ(H)	Plant Biotechnology- II	
BOT-661-MJP(A)	Practicals based on BOT-610-MJ(A) Advanced phycology - II	2
BOT-661-MJP(B)	Practicals based on BOT-610-MJ(B) Advanced Mycology-II	
BOT-661-MJP(C)	Practicals based on BOT-610-MJ(C) Angiosperms systematics - II	
BOT-661-MJP(D)	Practicals based on BOT-610-MJ(D) Plant Ecology-II	
BOT-661-MJP(E)	Practicals based on BOT-610-MJ(E) Advanced Plant Physiology -II	
BOT-661-MJP(F)	Practicals based on BOT-610-MJ(F) Pharmacognosy-II	
BOT-661-MJP(G)	Practicals based on BOT-610-MJ(G) Advanced Plant Genetics and Breeding -II	
BOT-661-MJP(H)	Practicals based on BOT-610-MJ(H) Plant Biotechnology- II	
	Total Major Elective Credits	4
BOT-681-RP	Research Project	6
	Total Credits for Semester-IV	22

SEMESTER III: CORE COURSES (Mandatory)		
BOT-601-MJ Molecular Biology-II (2 Credits: 30 Lectures)		**2C**
Credit 1: DNA and RNA		**15L**
1	Overview of DNA structure, physical and chemical properties and replication	**1L**
2	Packaging of genomes in viruses, bacteria and organelles	**2L**
3	DNA damage and repair	**2L**
4	Molecular mechanism of recombination and transposition	**2L**
5	Overview of RNA structure and transcription in prokaryotes and eukaryotes	**1L**
6	Processing of mRNA, tRNA & rRNA, alternative splicing	**2L**
7	mRNA localisation	**1L**
8	Ribozymes and riboswitches	**2L**
9	Non-coding RNAs, RNA interference	**2L**
Credit 2: Proteins and regulation of gene expression		**15L**
1	Protein synthesis - Overview	**2L**
2	Regulation of transcription - Regulation of trp operon by attenuation, Regulation of lytic and lysogenic cycles in phages	**4L**
3	Regulation of gene expression at higher levels of genome organization, chromatin remodeling, locus control regions, enhancers and insulators	**4L**
4	Regulation of protein synthesis, post-translational regulation, regulation of protein function	**5L**

Reference books:

1. Genes IX– Benjamin Lewin, Jones and Bartlett, 2008

2. Genes X– Benjamin Lewin, Jones and Bartlett, 2011

3. Molecular Biology of the Cell – Alberts, B, Bray, D, Raff, M, Roberts, K and Watson JD, Garland Publishers, 1999

4. Principles of Biochemistry – Lehninger, W.H. Freeman and Company, 2005

BOT-602-MJ Tools and Techniques in Botany-I (2 Credits: 30 Lectures)		2C
Credit 1		**15L**
1	**SI System of measurement:** Fundamental and derived units	**1L**
2	**Making solutions:** Moles and molarity, molar, molal, and percent solutions, stock solutions and dilutions, pH measurements and preparation of buffers	**2L**
3	**Electrochemical techniques:** Construction and working of equipment for measurement of electrical conductivity and pH	**2L**
4	**Measurement of water potential and osmolarity:** Osmolarity and osmotic pressure, osmolarity equation, types of osmometers, construction and working of osmometers	**2L**
5	**Gas exchange measurements:** Construction and working of Infrared Gas Analyser (IRGA), Clark electrode (O_2 electrode)	**2L**
6	**Radioactive techniques:** Isotopes and their half-lives, specific activity of radioisotopes, making radioisotope solutions, radiation counters, liquid scintillation counters, autoradiography	**3L**
7	**Microtomy:** Principles of tissue fixation for microtomy, types of microtomes, serial sectioning and staining	**3L**
Credit 2		**15L**
1	**Centrifugation techniques:** High speed centrifuges, rotors, ultracentrifugation, density gradient centrifugation	**3L**
2	**Crystallography and diffraction:** X ray crystallography, principle and working, biological macromolecular crystallography	**4L**
3	**Microscopy and microscopic techniques:** Light, dark, phase contrast, epifluorescence, electron and confocal microscopy, micrometry	**8L**

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1. David L. Nelson, Michael M. Cox Lehninger Principles of Biochemistry; W. H. Freeman 6th edition edition 2013.

2. David M Freifelder, Physical Biochemistry: Applications to Biochemistry and Molecular Biology (Life Sciences/Biochemistry, W. H. Freeman; 2nd Revised edition, 1983.

3. Jeremy M. Berg, John L. Tymoczko, Lubert Stryer Biochemistry, W. H. Freeman; 7th edition 2011.

4. Keith Wilson, John Walker, "Practical Biochemistry Principles and Techniques" Cambridge University Press 2010.

5. S. M. Khasim, "Botanical Microtechnique: Principles and Practice". Capital Publishing Company. 2002.

6. Thomas J. Kindt, Barbara A. Osborne and Richard Goldsby "Kuby Immunology ".W. H. Freeman; 6th edition 2006.

7. Bradbury, S. & Evennett, P. J. Contrast techniques in light microscopy. RMS Handbook No. 34. Bios Press. 1996.

8. Bradbury, S. (1989). Introduction to the optical microscope. (Revised edn.) RMS Handbook No 1. O.U.P.

9. Reiner Westermeier, Electrophoresis in Practice: A Guide to Methods and Applications of DNA and Protein Separations, Wiley-VCH Verlag GmbH & Co. KGaA, 2004.

10. Golakiya B A, Radio Tracer Techniques For Agriculturists And Biologists, New India Publishing Agency, June 2008.

BOT-603-MJ Climate change and plants (2 Credits: 30 Lectures)		2C
Credit 1 Concepts and policies		**15L**
1	Introduction to climate change: Overview of key concepts climate, weather and the greenhouse gas effect, important greenhouse gasses and their main sources, changes in the climate since the industrial revolution, impacts of climate change on surface temperature, precipitation, ocean pH, sea-level and Arctic sea-ice extent	**4L**
2	Greenhouse gasses: Role of industries in production of CFC products	**2L**
3	Climate change adaptation: Adaptations due to climate change at morphological, physiological, biochemical, reproductive levels in plants	**3L**
4	International policies and framework to address climate change: United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol and its associated bodies, Montereal protocol, national policies	**4L**
5	Net zero, renewable energy, empowering in safer future, green belt development	**2L**
Credit 2 Impacts and climate change mitigation strategies		**15L**
1	Climate change effects on agriculture: crops, crop cycles, soil quality and soil organic carbon	**5L**
2	Climate change impact on forest: Forest dispersion and shifting, forest fires, trees responses to temperature and water availability, increased CO2 concentration, carbon storage and nutrient availability	**5L**
3	Climate change mitigation: An overview of emissions levels and mitigation targets, international mechanisms to support climate change mitigation and low carbon development	**5L**

References

1. Aldy, J & Pizer, W 2014, Comparability of Effort in International Climate Policy Architecture, Discussion Paper 2014-62, Harvard Project on Climate Agreements, Cambridge, Mass.
2. Bodansky, D 2010, The International Climate Change Regime: The Road from Copenhagen, Policy Brief, Harvard Project on Climate Agreements, Belfer Centre for Science and International Affairs, Harvard Kennedy School.
3. Bodansky, D 2012, The Durban Platform Negotiations: Issues and Options for a 2015 agreement, Centre for Climate and Energy Solutions, Washington D.C.
4. Clarke, L, Jiang, K, Akimoto, K, et al. 2014, 'Assessing Transformation Pathways', in Climate Change 2014: Mitigation of Climate Change, Working Group III contribution to the IPCC 5th Assessment Report, Intergovernmental Panel on Climate Change, Geneva.

5. Climate Change Authority 2014, Reducing Australia's Greenhouse Gas Emissions—Targets and Progress Review, Final Report, Climate Change Authority, Melbourne.
6. Climate Change Authority 2014a, Using International Emissions Reductions To Help Meet Australia's 2020 Target, (forthcoming) Climate Change Authority, Melbourne.
7. The Climate Institute 2014, Moving Below Zero: Understanding Bio-energy with Carbon Capture and Storage, Sydney.
8. den Elzen, M & Höhne N 2008, 'Reductions of greenhouse gas emissions in Annex I and non-Annex I countries for meeting concentration stabilisation targets, An editorial comment,' Climatic Change, 91:249–274 DOI 10.1007/s10584-008-9484-z.
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10. Department of the Environment 2014, Emissions Reduction Fund – White Paper, Canberra.
11. Garnaut, R 2008, The Garnaut Climate Change Review – Final Report, Commonwealth of Australia, Cambridge University Press, Melbourne.
12. GLOBE International 2013, Climate legislation study—a review of climate change legislation in 33 countries, third edition, Climate and Development Knowledge Network, Antony Rowe, Chippenham.
13. Gupta, S, Tirpak, D, Burger, N, et al. 2007, 'Policies, Instruments and Co-operative Arrangements', in Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Metz, B, Davidson, O, Bosch, O, Dave, R, Meyer, L (eds)), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
14. Haites, E, Yamin, F, Hohne, N 2013, Possible Elements of a 2015 Legal Agreement on Climate Change, IDDRI, Working Papers, No. 16/13, Paris.
15. Hale, T & Harris, M 2014, Country-to-Country Review under the Next Climate Treaty: Lessons from other Intergovernmental Review Processes, Policy memo: 24 February 2014, Blavatnik School of Government, University of Oxford.
16. Hood, C, Briner, G & Rocha, M 2014, GHG or not GHG: Accounting for Diverse Mitigation Contributions in the Post-2020 Climate Framework. Climate Change Expert Group, Paper No. 2014(2), OECD, International Energy Agency, Paris.
17. International Energy Agency 2013, Policies and Measures Database, viewed 22 May, Paris, http://www.iea.org/policiesandmeasures/(Opens in a new tab/window).
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19. Kee, HL, Ma, H & Mani, M 2010, The Effects of Domestic Climate Change Measures on International Competitiveness, Policy Research Working Paper 5309, The World Bank Development Research Group Trade and Integration Team and Environment Department, World Bank, Washington D.C.
20. Levin, K & Finnegan, J 2013, Designing National Commitments to Drive Measurable Emissions Reductions After 2020, Working Paper, World Resources Institute, Washington D.C.

21. Mazouz, S & Jackson, E 2012, Emissions Trading Coalitions. Leveraging Emission Trading to Achieve Greater Levels of Global Mitigation Ambition, Discussion Paper, The Climate Institute, Sydney.
22. Morgan, J, Tirpak, D, Levin, K & Dagnet, Y 2013, A Pathway to a Climate Change Agreement in 2015: Options for Setting and Reviewing GHG Emission Reduction Offers, World Resources Institute, Washington D.C.
23. Olsen, KH, Fenhann, J & Lutken, S 2013, Elements of a New Climate Agreement by 2015, Perspective Series 2013, UNEP Risoe Centre, Roskilde.
24. Prinn, R 2013, 400 ppm CO2? Add Other GHGs, and It's Equivalent to 478 ppm, online interview, viewed 11 June 2014, http://oceans.mit.edu/featured-stories/5-questions-mits-ron-prinn-400-
25. Rajamani, L 2012, 'The Durban Platform for Enhanced Action and the future of the climate regime,' International and Comparative Law Quarterly, vol. 61, pp. 501–18.
26. Redondo, ED 2012. 'The Universal Periodic Review – Is There Life Beyond Naming and Shaming in Human Rights Implementation?, New Zealand Law Review, vol. 4.
27. Reisinger, A, Kitching, R, Chiew, F, et al. 2014, 'Australia and New Zealand', in Climate Change 2014: Impacts, Adaptation and Vulnerability, Working Group II contribution to the IPCC 5th Assessment Report, Intergovernmental Panel on Climate Change, Geneva.
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29. Rocha, MT 2013, Elaborating the 'framework for various approaches' under the UNFCCC, Discussion Document,OECD, Paris.
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32. Rogelj, J 2013, Scenario Note—Pathways towards Returning Warming to below 1.5°C by 2100: Briefing Note to the Climate Institute, Climate Analytics, Berlin.
33. Spencer, T & Hipwell, E 2013, 'Coordinating, Mandating, Monitoring: What Can the Post 2015 Climate Regime Learn from Global Financial Governance?', Carbon Climate Law Review, vol. 4, pp. 293–305.
34. Stavins, R, Ji, Z, Brewer, T, et al. 2014, 'International Cooperation: Agreements & Instruments', in Climate Change 2014: Mitigation of Climate Change, Working Group III contribution to the IPCC 5th Assessment Report, Intergovernmental Panel on Climate Change, Geneva.
35. The Treasury and DIICCSRTE 2013, Climate Change Mitigation Scenarios, Modelling report provided to the Climate Change Authority in support of its Caps and Targets Review, Government of Australia, Canberra. United Nations Environment Programme (UNEP) 2013, The Emissions Gap Report, UNEP, Nairobi.
36. United Nations Framework Convention on Climate Change (UNFCCC) Secretariat 2011, Compilation of economy-wide emissions reduction targets to be implemented by parties included in Annex I to the Convention, FCCC/SB/2011/INF.1/Rev.1, 7 June.

37. UNFCCC Secretariat 2013, Compilation of information on nationally appropriate mitigation actions to be implemented by Parties not included in Annex I to the Convention, FCCC/SBI/2013/inf.12/rev.2, 28 May 2013.
38. United States Energy Information Administration (EIA) 2014, Short-term Energy Outlook, May 2014, Washington D.C.
39. United States Environment Protection Agency (EPA) 2014, Clean Power Plan Proposed Rule, May 2014, Washington D.C.
40. Weischer, L, Morgan, J & Patel, M 2012, 'Climate Clubs: Can Small Groups of Countries make a Big Difference in Addressing Climate Change?', Review of European Community & International Environmental Law, vol. 21, pp. 177–92.
41. Werksman, J 2010, 'Legal symmetry and legal differentiation under a future deal on climate,' Climate Policy, vol. 10:6, 672–7, DOI: 10.3763/cpol.2010.0150.
42. Winkler, H & Rajamani, L 2013, 'Common but differentiated responsibilities and respective capabilities in a regime applicable to all,' Climate Policy, DOI:10.1080/14693062.2013.791184.
43. Winkler, H 2014, International requirements for transparency of mitigation actions, Input by ERC to the Department of Environmental Affairs, Energy Research Centre, University of Cape Town.

BOT-604-MJ Plant genetic engineering (2 Credits: 30 Lectures)		**2C**
Credit 1: Basics of recombinant DNA technology (RDT)		**15L**
1	Enzymes used in RDT: restrictions endonucleases, ligases, kinase, TDT, polymerases, phosphatase, reverse transcriptase	**1L**
2	Vectors: plasmids, lambda based vectors, phagemid, cosmid, BAC and YAC	**3L**
3	PCR and its types	**1L**
4	Blotting techniques: Southern, Northern and Western	**2L**
5	Cloning methods: restriction ligation, TA, gateway, golden gate, Gibson assembly	**3L**
6	DNA Sequencing: History, Sanger, Illumina, ONT and PacBio long read platforms	**3L**
7	Gene expression techniques: quantitative PCR, RNAseq	**2L**
Credit 2: Methods and applications of plant transformation		**15L**
1	Transgenic plants: selection of vector, selection of promoter, constitutive, tissue specific, conditional, marker genes and antibiotics	**4L**
2	Methods for plant transformation: Physical and chemical	**2L**
3	Agrobacterium mediated plant transformation: Mechanism of T-DNA transfer, binary vector, co-cultivation, selection and regeneration	**4L**

4	Applications of transgenic crops: Biotic and abiotic stress, nutritional value and improvement of quality	**3L**
5	Biosafety concerns related to transgenic plants	**2L**

Suggested Readings:

1. Recombinant DNA – Principles and Methodologies. Greene JJ and Rao VS, Marcel Dekker, New York, 1998.
2. Principles of gene manipulation. Primrose SB, Twyman RM and Old RW, 6th Edition, Blackwell Science, Oxford, 2001
3. Engineering plants for commercial products and applications. Eds. Collins GB and Shepherd RJ, NY Acad. Of Science Publishers 1996
4. DNA markers.Eds. Caetano-Anolles and Gresshoff, Wiley-VCH Publishers, NY, 1998
5. Bioinformatics. Westhead, DR, Parish JH and Twyman, RM, BIOS Scientific Publishers Ltd., Oxford, 2003
6. Collins GB and Shepherd RJ Eds., 1996, Engineering plants for commercial products and application. NY Acad. Of Science Publishers
7. Senson CW Edt, 2002, Essentials of Genomics and Bioinformatics,. Wiley-VCH Publishers, NY.
8. Charlwood B.V. and Rhodes MV Edt. 1999, Secondary products from plant tissue culture. Clarendon Press, Oxford.
9. Dicosmo F and Misawa M, Edt 1996, Plant cell culture: Secondary metabolism towards industrial application, CRC press, Boca Raton, N.Y.
10. Ramawat K G and Merillon J M, Edt.1999 Biotechnology: Secondary metabolites, Oxford IBH Publishing Co., New Delhi.
11. Buchanan BB, Grussem Wand Jones RL, 2000, Biochemistry and molecular biology of plants, IK International Pvt Ltd. New Delhi.
12. Verapoorte R and Alferman HW Eds, 2002 Metabolic engineering of plant secondary metabolites. Kluwar Academic Publ., Netherlands.

BOT-605-MJ Plant Development-II (2 Credits: 30 Lectures)		**2C**
Credit 1 – Reproductive development		**15L**
1	Flower development: molecular basis - ABC & ABCE models	**3L**
2	Development of stamen, anther, sporogenous tissue, tapetum, microsporogenesis, pollen and male gametophyte	**2L**
3	Development of ovule, integuments, sporogenous tissue, megaspore, female gametophyte	**2L**
4	Molecular basis of male and female gametophyte development	**2L**
5	Interaction between pollen & pistil, pollen tube guidance, self-incompatibility, double fertilization and triple fusion, role of synergids, endosperm development and imprinting	**3L**
6	Structure of seed, germination and mutants	**1L**

7	Stages of embryogenesis, structure and organization of embryo, suspensor, embryogenesis mutants and establishment of body plan	**2L**
Credit 2 - Intrinsic and extrinsic factors regulating plant development		**15L**
1	Light mediated regulation: a. Photoreceptors- phytochromes, cryptochromes, phototropins b. Signal transduction leading to photomorphogenesis and photoperiodic responses c. Circadian rhythms	**2L** **3L** **2L**
2	Hormonal regulation a. Perception, signalling and regulation of gene expression by hormones - Hormone receptors, mutants in hormone signalling, transcription factors involved in hormone signalling b. Role of hormones in germination, growth and flowering. Cross-talk between hormone signalling pathways	 **4L** **3L**
3	Regulation of development by metabolites (sugars and Nitrogen)	**1L**

References

1. The Arabidopsis Book. (www.arabidopsisbook.org)
2. Bhojwani S. S., Dantu P. K. and Bhatnagar S. P. (2014). The Embryology of Angiosperms. (6th Edition) Vikas Pub. House.Paperback edition.
3. Bhojwani S.S. and Soh W.Y. (2001). Current Trends in Embryology of Angiosperms, Kluwer Academic Publishers.
4. Buchanan B. B., Gruissem W. and Jones R. L. (2015) Biochemistry and Molecular Biology of Plants. Second Edition.Wiley Blackwell.
5. Burgess J. (1985) An Introduction to Plant Cell Development. Cambridge University Press.
6. Davies P. J. (Editor) (2004) Plant Hormones. Biosynthesis, Signal Transduction, Action Springer Publications.
7. Fahn A. (1990) Plant Anatomy (4th Edition) Pergamon Press, London, New York.
8. Gilbert S. F. (2013). Developmental Biology (10th Edition). Sinauer Associates, Inc., Massachusetts, USA.
9. Graham C.F. and Wareing P.F. (1984). Developmental Control in Animals and Plants. Blackwell Scientific Publications, UK.
10. Johri B. M. and Srivastava P. S. (2001). Reproductive Biology of Plants. Narosa Publishing House, New Delhi.
11. Jones R., Ougham H., Thomas H. and Waaland S. (2013) The Molecular Life of Plants. Wiley Blackwell.
12. Krishnamurthy K.V. (1988) Methods in Plant Histochemistry. S. Viswanathan Printers & Publishers.
13. Lyndon R.F. (1990) Plant Development The Cellular Basis. (Topics in Plant Physiology, Vol. 3) Springer Publications.
14. Leyser O. and Day S. (2009) Mechanisms in Plant Development. Wiley Blackwell.
15. Raghavan V. (2000) Developmental Biology of Flowering Plants. Springer Verlag.
16. Razdan M.K. (2003) Introduction to Plant Tissue Culture, Second Edition. Science Publishers Inc., USA, UK.
17. Wada M., Shimazaki K., Iino M. (2005). Light sensing in plants. Springer.
18. Wareing P. F. and Philips I. D. J. (1981) Growth and Differentiation in plants. Pergamon Press
19. Wolpert L., Tickle C. and Arias A. M. (2015) Principles of Development. (5th Edition) Oxford University Press.

BOT-606-MJP Practical based on BOT 601 MB-II & BOT 602 TTB-I (2 Credits: 15 Practicals)		**2C**
Practicals on molecular biology (Any 8)		
1	Restriction digestion of plasmid DNA and gel electrophoresis	**2P**
2	Demonstration of DNA ligation and separation of ligated DNA on agarose gel	**2P**
3	Primer designing, amplification of DNA fragment/gene using PCR and separation of PCR products	**4P**
4	Isolation of plant total RNA and quantification	**2P**
5	Formaldehyde denaturing gel electrophoresis for total RNA separation	**1P**
6	SDS-PAGE based separation of globulin seed storage protein and determination of molecular weight	**3P**
Practicals on tools and techniques in botany -I (Any 7P)		
1	Absorption spectra of BSA / DNA and determination of absorption maxima, molar extinction coefficient	**2P**
2	Plant tissue sectioning using cryomicrotome	**1P**
3	Estimation of photosynthetic rate using IRGA	**1P**
4	Demonstration of Oxygen measurement system	**1P**
5	Determination of pKa and buffering capacity of acetate buffer	**2P**
6	Electrical conductivity measurement of different solutions	**2P**
7	Epifluorescence microscopy	**1P**
8	Measurement of cell dimensions using micrometry	**1P**

BOT-607-MJP Practicals based on BOT-603-MJ climate change and plants, BOT-604-MJ Plant genetic engineering & BOT 605 plant development - II (2 Credits: 15 Practicals)		**2C**
Practicals based on climate change and plants (Any 5P)		
1	Measurement of photosynthetic rate and stomatal conductivity under elevated carbon concentrations	**2P**
2	Measurement of photosynthetic rate under elevated temperature	**2P**
3	GIS based measurement of vegetation	**2P**
4	Effect of elevated CO2 levels on seed germination and growth	**2P**
5	Water quality assessment using multiparameter water analyser	**2P**
6	Effect of climate change on plant disease incidences	**2P**

Practicals based on plant genetic engineering (Any 5P)		
1	PCR amplification of the gene/gene fragment and cloning into vector	**2P**
2	Transformation in *E. coli* using heat shock method and selection of transformants	**3P**
3	Restriction digestion of plasmid and separation of DNA fragments using agarose gel electrophoresis	**2P**
4	Colony PCR based screening of recombinant clones	**2P**
5	Sanger sequencing data analysis	**1P**

Practicals based on plant development - II (Any 5P)		
1	Observations on: a. Microsporogenesis and development of male gametophyte b. Megasporogenesis and development of female gametophyte	**2P**
2	Isolation and studies on types of endosperm	**1P**
3	Isolation and studies on types of embryo development	**1P**
4	*In vitro* germination of microspore/pollen. Correlation between fertility and viability of pollen	**2P**
5	Isolation and histochemical characterisation of floral meristem	**1P**

BOT-610-MJ(A) Advanced Phycology- I (2 Credits: 30 Lectures)		2C
Credit 1		**15L**
1	Approaches in the study of algal systematics	**1L**
2	Cyanophyta: Botanical and bacteriological codes for nomenclature, Kenyon-Murata classification system, traditional and modern trends in the classification	**3L**
3	Chlorophyta: Morphology & ultrastructure based concepts. Use of mitotic, cytokinesis, chloroplast, pyrenoid and eyespot characteristics in systematic studies	**4L**
4	Charophyta: Evolution and origin of land plants	**1L**
5	Ochrophyta: Environmental factors controlling life cycles, Phlorotannins and physodes, modern trends in the classification	**2L**
6	Rhodophyta: Modern trends in the classification	**2L**
7	Brief overview of phylogeny of Xanthophyceae, Eustigmatophyceae, Bacillariophyceae, Dinophyceae, and Euglenophyceae	**2L**
Credit 2		**15L**
1	Phytoplankton: Classification, sampling methods, primary productivity, nutrient uptake models (Michaelis - Menten, and Monod, Droop models)	**3L**
2	Algae in marine environment: Physico-chemical properties, intertidal seaweeds, zonation patterns and factors affecting distribution of intertidal seaweeds	**3L**
3	Algal adaptation to nutrient availability (Carbon, Nitrogen and Phosphate)	**2L**
4	Cyanobacterial symbioses with fungi and other plants, cellular responses during symbiosis	**2L**
5	Extremophilic algae and their survival mechanisms	**3L**
6	Algae: Bioindicators and bioluminescence	**2L**

References

1. Archibald, J. M., Simpson, A. G. B. and Slamovits, C. H. (eds.) (2017). *Handbook of the protists* (2nd ed.). Springer International Publishing AG, pp. 1657.

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3. Bhattacharya, D. (ed.) (1997). *Origins of algae and their plastids, Plant systematics and evolution supplement 11*. Springer-Verlag Wien, pp. 287.

4. Brodie, J. and Lewis, J. (eds.) (2007). *Unravelling the algae: the past, present, and future of algal systematics*. CRC Press, Boca Raton, pp. 376.

5. Graham, L. E. and Wilcox, L. W. (2000). *Algae*. Prentice Hall, Inc., NJ, pp. 640.

6. Hoek, C. Van Den, Mann, D. G. and Jahns, H. M. (2009). *Algae: An introduction to Phycology*. Cambridge University Press, New Delhi, pp. 623.

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9. Pal, R. and Choudhury, A. K. (2014). *An introduction to phytoplanktons: Diversity and ecology*. Springer, India, pp. 167.

10. Pawlowski, K. (ed.) (2009). *Prokaryotic symbionts in plants –Microbiology Monographs, Volume 8*. Springer-Verlag Berlin Heidelberg, pp. 306.

11. Pereira, L. and Neto, J. M. (eds.) (2015). *Marine algae: Biodiversity, Taxonomy, Environmental Assessment, and Biotechnology*. CRC Press Boca Raton, pp. 390.

12. Round, F. E. (1984). *The Ecology of Algae*. Cambridge University Press.

13. Sahoo, D. and Seckbach, J. (2015). *The algae world (Cellular origin, life in extreme habitats and astrobiology 26*). Springer Science, Dordrecht, pp. 598.

14. Sarma, T. A. (2013). *Handbook of cyanobacteria*. CRC Press, Boca Raton, pp. 802.

15. Seckbach, J. (ed.) (2007). *Algae and cyanobacteria in extreme environments (Cellular origin, life in extreme habitats and astrobiology 11)*. Springer, Dordrecht, The Netherlands, pp. 811.

16. Singh, B., Bauddh, K. and Bux, F. (eds.) (2015). *Algae and environmental sustainability (Developments in applied phycology 7)*. Springer, India, pp. 181.

17. Singh, P. K., Kumar, A., Singh, V. K. and Shrivastava, A. K. (eds.) (2020). *Advances in cyanobacterial biology*. Elsevier Inc., UK, pp. 403.

BOT-611-MJP(A) Practicals based on BOT-610-MJ(A) Advanced Phycology – I (2 Credits: 15 Practicals)		2C
1	Collection, characterization and identification of algae from diverse habitats	**4P**
2	Morphometric studies of algae	**1P**
3	Estimation of phytoplankton primary productivity	**2P**
4	Isolation and identification of symbiotic algae from lichen/ *Anthoceros/ Azolla*	**3P**
5	Documenting algal biofilm development on an artificial substratum/habitat	**2P**
6	Karyological studies in eukaryotic algae	**1P**
7	Use of algal databases and other online resources	**1P**
8	DNA extraction and amplification by using primers based on 18/16s rRNA or ITS from algae	**3P**
9	Construction of phylogenetic tree based on conserved genes in algae	**2P**
10	Effect of heavy metal/salinity stress on microalgae	**2P**
11	Effect of nitrogen/phosphorus on the growth of microalgae	**2P**
12	Effect of light intensities on the growth of microalgae	**2P**
13	Study of desiccation stress tolerance in algae	**2P**
14	Preparation of herbarium specimens (wet and dry)	**2P**

BOT-610-MJ(B) Advanced Mycology-I (2 Credits: 30 Lectures)		2C
Credit 1-Fungal systematics		**15L**
1	Systematic, origin, evolution and phylogeny of fungi: Natural and molecular method of fungal systematics	**2L**
2	Overview of a higher level phylogenetic classification of fungi (Hibbett et al 2007 and Kirk 2008)	**1L**
3	Subkingdom- Dikarya: Ascomycota and Basidiomycota; Phylum: Chytridiomycota; Phylum: Blastocladiomycota; Phylum: Neocallimastigomycota; Phylum: Glomeromycota: Phylum: Microsporidia; Sub-	**12L**

	phylum: Enomophthoromycotina; Sub-Phylum: Mucoromycotina; Sub-Phyllum: Zoopagomycotina; Sub-Phylum: Kickxellomycotina	
Credit 2- Fungal physiology and applications		**15L**
1	Heterothallism, heterokaryosis and parasexual cycle	**2L**
2	Physiological specialization and fungal sex hormones	**3L**
3	Biodegradation of waste - solid and liquid waste management through fungi	**5L**
4	Application of fungi in biodegradation: Cellulose, hemicelluloses, pectic compounds, lignin, Fungi in bioremediation	**5L**

References

1. Ainsworth and Bisbys Dictionary of the fungi (10thed) by Kirk et. al. 2008 C.A.B. International, Oxon, UK.
2. Hibbett DS, Binder M, Bischoff JF, Blackwell M, Cannon PF, Eriksson OE, et al. (2007). "A higher level phylogenetic classification of the Fungi" (PDF). Mycological Research 111(5): 509–547. doi:10.1016/j.mycres.2007.03.004. PMID 17572334.
3. 21centuary guidebook of fungi, David Moore, Geoffrey D. Robson, Anthony P. J. Trinci:Cambridge University Press. 2011.
4. Introduction of Fungi by John Webster and Roland Weber, Third edition, Cambridge University Press, 2007.
5. Introductory Mycology by Alexopolous J., Mims C. W. and M. Blackwell, fourth edition, Wiley India Pvt Ltd, 2007.
6. Topics in Mycology and Pathology by L. N. Nair, first edition, New Central Book Agency Kolkata, 2007.
7. Fungal Biology by J. W. Deacon, Fourth edition, Blackwell Publishing Ltd, 2006.
8. Biodiversity of fungi: Inventory and Monitoring methods by M. S. Foster, G. F. Wills and J. M. Mueller, first edition, Academic Press, 2004.Practicals:
9. Mycoremediation: Fungal Bioremediation by Harbhajan Singh, first edition, John Wiley and Sons, Hoboken, New Jersey, 2006.
10. An introduction to fungi: by H.C. Dube, Scientific publisher India, fourth edition, 2015.

BOT-611-MJP(B) Practicals based on BOT-610-MJ(B) Advanced Mycology-I (2 Credits: 15 Practicals)		2C
1	Study of the representative genera belonging to all the group of fungi with respect to observations made based on tissue differentiation, accessory organs, asexual and sexual structures, and fruiting body	**4P**
2	Study of fungal cellulase and hemicellulase activity	**3P**
3	Isolation and culture of fungi from rotting wood/ oil spills/ leaf litter	**3P**
4	Slide culture technique for *in vivo* study of fungi	**2P**
5	Sensitivity of fungicides on fungal cultures	**2P**
6	DNA isolation, primer designing and PCR amplification of MAT genes	**4P**
7	Isolation and quantification of fungal hormones	**2P**

BOT-610-MJ(C) Angiosperms systematics – I (2 Credits: 30 Lectures)		2C
Credit 1		**15L**
1	Taxonomy: Phases of taxonomy, taxonomy as synthetic discipline. Botanical nomenclature: Scientific names, principles, typification, effective and valid publication	**4L**
2	Apomorphies of Angiosperms: Flower, stamen, reduced male and female gametophyte, carpel, double integuments, endosperm formation, sieve tube members, vessels, etc.	**3L**
3	Taxonomic hierarchy: Ranks of taxa; Major categories: Division, class, order, family; Minor categories: genus, species and infraspecific categories	**3L**
4	Taxonomic tools and literature: Botanical keys, their merits and demerits. Type specimens and protologue, journals and websites	**2L**
5	Evolutionary concepts and principles: Causes of variations in population, population and environment	**3L**
Credit 2		**15L**
1	Morphological and biological species concept: Allopatric, abrupt, sympatric, hybrid and apomictic speciation	**2L**

2	Isolating mechanisms in plant speciation: Premating- temporal, habitat, floral, reproductive mode; post mating, prezygotic- incompatibility; post mating, postzygotic- incompatibility, hybrid inviability, hybrid floral isolation, hybrid sterility, hybrid breakdown	**3L**
3	Morphological variations, systematic position, interrelationships, phylogeny and economic importance of following clades: ANA Grade- Hydatellaceae; Magnoliids- Lauraceae, Aristolochiaceae; Monocots- Hydrocharitaceae, Asparagaceae, Commelinaceae, Eriocaulaceae, Musaceae Eudicots- Nelumbonaceae; Core Eudicots- Nyctaginaceae; Superrosids- Vitaceae, Rosids-I: Cucurbitaceae, Rosaceae; Rosids-II: Capparaceae, Brassicaceae; Superrosids: Loranthaceae, Santalaceae; Euasterids-I: Rubiaceae, Apocynaceae; Euasterids-II**:** Araliaceae; Certaophyllaceae	**10L**

References

1. Angiosperm Phylogeny Group (2016) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society* 181: 1–20.
2. Cronquist, A. 1981. An Integrated System of Classification of Flowering Plants. Columbia University Press, New York.
3. Davis, P. H. and V. H. Heywood 1991. Principles of Angiosperm Taxonomy. Today and Tomorrow Publications, New Delhi
4. Douglas E. Soltis, Pamela E. Soltis, Peter K. Endress and Mark W. Chase, 2005. Phylogeny and Evolution of Angiosperms. Sinauer Associates, Inc., Publishers, Sunderland, USA.
5. Eshbaugh, W.H. Systematics Agenda 2000: an historical perspective. *Biodivers Conserv* 4, 455–462 (1995). https://doi.org/10.1007/BF00056336
6. Ian J. Kitching, Peter L. Forey, Christopher J. Humphries and David M. Williams, 1998. Cladistics: The Theory and Practice of Parsimony analysis (2nd Ed.). The Oxford University Press.
7. Lawrence George H. M. 1951. Taxonomy of Vascular plants Oxford and IBH Publ. Co. Pvt. Ltd., New Delhi
8. Manilal, K. S. and M. S. Muktesh Kumar (ed.) 1998. A Hand book of Taxonomy Training, DST, New Delhi
9. Naik, V. N. 1984. Taxonomy of Angiosperms Tata McGrow-Hill Publication Com. Ltd., New Delhi
10. Pandey, Arun K. and Shruti Kasana. 2021. *Plant Systematics*. Taylor & Francis Ltd. Edition 1st Edition. Pages 340. DOI https://doi.org/10.1201/9781003183464
11. Quicke, D.L.J. 1993. Principles and Techniques of Contemporary Taxonomy. Blackie Academic & Professional (An imprint of Chapman & Hall.).
12. Radford, A.E., W.C. Dickinson, J.R. Massey and C.R. Bell. 1974. Vascular Plant Systematics, Harper & Row, New York.
13. Simpson, Michael George. 2006. Plant systematics. Elsevier Academic Press.
14. Singh, Gurcharan. 2019. Plant Systematics: An Integrated Approach, Fourth Edition. CRC Press.7.

15. Sivarajan, V.V. 1991. (2nd ed.). Introduction to the Principles of Plant Taxonomy (Ed. N S K Robson). Oxford & IBH publishing Co. Pvt. Ltd.
16. Stace, C. A. 1989. Plant Taxonomy and Biosystematics Etwaed Arnold, London.
17. Stevens, P. F. (2001 onwards). Angiosperm Phylogeny Website. Version 9, June 2008 [and more or less continuously updated since]. http://www.mobot.org/MOBOT/research/APweb/
18. Stuessy Tod F. 2002. Plant taxonomy. The systematic Evaluation of comparative data. Bishen Singh Mahendra Pal Singh, Dehra Dun.
19. Stuessy, Tod F., 2009. Plant taxonomy: the systematic evaluation of comparative data (2nd ed.). New York: Columbia University Press.
20. Takhtajan, A. 1986. Floristic Regions of the World. University of California Press.
21. Taylor, D. V. and L. J. Hickey 1997. Flowering plants: Origin, evolution and phylogeny CBS Publishers a Distributors New Delhi.
22. Walter S. Judd, Christopher S. Campbell, Elizabeth A. Kellogg, Peter F. Stevens and Michael J. Donoghue. 2007. Plant Systematics: A Phylogenetic Approach, Third Edition. Sinauer Associates, Inc., Publishers, Sunderland, USA.

BOT-611-MJP(C) Practicals based on BOT-610-MJ(C) Angiosperms systematics -I (2 Credits: 15 Practicals)		**2C**
1	To study apomorphies of various clades	**4P**
2	Preparation of taxonomic keys for identifications of plants	**2P**
3	Identification of genus and species of locally available wild plants using regional and state Floras (3 specimens for each practical)	**5P**
4	Methodology to describe a new taxon as per ICN	**2P**
5	Identification of plant specimens in the field (at least 50 species).	**2P**
6	Methodology to study type specimens and protologue	**3P**
7	Preparation of herbarium specimens (dry and wet)	**3P**

BOT-610-MJ(D) Plant Ecology-I (2 Credits: 30 Lectures)		**2C**
Credit 1: Ecosystem ecology		**15L**
1	Development, structure and functions of ecosystem	**2L**
2	Major biomes in India and the world, global species distribution patterns, special habitats	**3L**

3	Biodiversity hotspots, endemism, *in-situ* and *ex-situ* conservation	**3L**
4	Perturbation in ecosystems: Natural and anthropogenic, restoration ecology	**2L**
5	Environmental legislations: IUCN, Kyoto protocol, Paris agreement, CBD and CDM, intergovernmental panel on climate change, Biological diversity act 2002	**5L**
Credit 2: Behavioral and chemical ecology		**15L**
1	Behavioral Ecology: Introduction and causes, differentiating behavior of cognition, and consciousness in plants	**4L**
2	Adaptations for survival and reproduction in plants: Camouflage, defensive coloration, and mimicry, types and mechanisms; continuous vs monocarpic reproduction	**5L**
3	Chemical ecology: Plant organism interaction, tritrophic interaction, attraction of pollinators, plants responses to oviposition	**3L**
4	Plant migration and dispersal ecology	**3L**

Suggested Readings:

1. Begon, M., Townsend, C. R. and Harper, J. L. (2005). *Ecology: From individuals to Ecosystems* 4th edition, Wiley-Blackwell.

2. Odum, E. P. (2007) *Fundamentals of Ecology*, 5th edition, Thomson books.

3. Coleman, D.C., Crossley, D. A. and Handrix, P. F (2004) *Fundamentals of Soil Ecology*, 2nd edition, Elsevier academic press.

4. Ambhast, R. S. (1998) *A Text Book of Plant Ecology*, 9th edition, Friend and Co.

5. Canter L (1996) *Environmental Impact Assessment*, 2nd Edition, McGraw Hill Publishing Company.

6. Gurevitch, J., Scheiner, S. M. and Fox, G. A. (2006) *TheEcology of Plants*, Sinauer Associates.

7. Hynes, H. B. N. (1978) *Biology of Polluted Water*, 1st edition, Liverpool University Press.

8. Sutherland, W. J. (Ed.). (2006). *Ecological Census Techniques: AHandbook*. Cambridge University Press.

9. Mittelbach, G. G., & McGill, B. J. (2019). *Community Ecology*. Oxford University Press.

10. Trewavas, A. (2014). *Plant Behaviour and Intelligence*. OUP Oxford.

11. Wohlleben, P. (2016). *The hidden life of trees: What they feel, how they communicate—Discoveries from a secret world* (Vol. 1). Greystone Books.

12.Schulze, E. D., Beck, E,, Buchmann, N,, Clemens, S,, Müller-Hohenstein, K. and Scherer-Lorenzen (2019). *Plant Ecology*. Springer

13. Misra R and Puri GS (2018). *Indian Manual of Plant Ecology*. Scientific Publishers (India)

14. Jose, S., Singh, H. P., Batish D. R. andKohli, R.K. (2013). *Invasive Plant Ecology*. CRC Press.

15. Pugnaire, F.I. andValladares, F. (2007). *Functional Plant Ecology*. CRC Press

16.Hasanuzzaman, M., Fujita, M., Oku, H, andTofazzal Islam, M. (2019). *Plant Tolerance to Environmental Stress*. CRC Press

17. Dighton, J. (2018). *Fungi in Ecosystem Processes*. CRC Press

18. Cronk, J. K. and Siobhan Fennessy, M. (2001). *Wetland Plants*. CRC Press

19. Lemon, E. R. (2019). *CO2 and Plants*. The Response of Plants to Rising Levels of Atmospheric Carbon Dioxide. CRC Press

20. Davet, P. (2004). Microbial Ecology of Soil and Plant Growth. CRC Press

21. Schulze, E.D., Beck, E. and Muller-Hohenstein, K. (2002). Plant Ecology. Springer

BOT-611-MJP(D) Practicals based on BOT-610-MJ(D) Plant Ecology-I (2 Credits: 15 Practicals)		**2C**
1	Study of plant adaptations in epiphytes and parasites	**3P**
2	Assessment of plant species based on IUCN criteria	**2P**
3	Study of plant adaptation related to survival and reproduction	**2P**
4	Study of plant mimicry	**1P**
5	Study of pollination mechanisms	**2P**
6	Studying plant microbes/ insect interaction	**2P**
7	Case studies of the ecosystems and preparation of report	**2P**
8	Detection of green leaf volatiles after herbivory	**2P**
9	Study of different types of insect herbivores	**2P**

10	Visit to Botanic garden/ institutes involved in conservation	**1P**
11	Study of biomass production in an ecosystem	**2P**

BOT-610-MJ(E) Advanced Plant Physiology-I (2 Credits: 30 Lectures)		**2C**
Credit 1: Photosynthesis and respiration		**15L**
1	Chlorophyll fluorescence kinetics and determination of PSI, PSII efficiency, CO_2 compensation point. Photoinhibition and protection mechanisms, photorespiration	**4L**
2	Evolution and diversity of photosynthetic systems. Evolution of RuBPCase and Calvin cycle. Partitioning of photosynthetic assimilates under different conditions, feedback regulation of photosynthesis	**4L**
3	Alternative oxidase pathway in plants, regulation of respiration, GABA shunt. Inhibitors and uncouplers of mitochondrial electron transport chain, diverse electron transport systems in plant mitochondria.	**4L**
4	Interdependence of mitochondria and chloroplasts. Protective effects of mitochondrial respiration on photosynthesis, growth and maintenance respiration. Role of respiration in plant carbon balance	**3L**
Credit II: Crop physiology		**15L**
1	Crop growth analysis - CGR, RGR, NAR, LAI, LAD and LAR, factors affecting phenology and yield, root- shoot relationship	**6L**
2	Agrometeorological observations, data recording, analysis, presentation and interpretation. Correlation studies of weather data and crop growth	**3L**
3	Competitive relationships and competitive functions, biological and agronomic basis of yield advantage under intercropping	**3L**
4	Dryland crop production, constraints and remedial measures, heat unit concept of crop maturity, types of heat unit	**3L**
Suggested Readings:		
1. Berg J.M., Tymoczko J.L., Stryrer L. (2002) Biochemistry. 5th Ed. Wlt. Freeman and Company, New York.		

2. Buchanan B.B., Gruissem W., Jones R.L. (2000) Biochemistry and Molecular Biology of Plants. IK International, Mumbai.

3. Davis P. J. (Eds.).(2004) Plant Hormones. Kluwer Academic Publishers, Dordrecht, Netherlands.

4. Goodwin T.W., Mercer E.I. (1998) Introduction to Biochemistry. CBS Publishers, New Delhi. 4. Heldt H. W. (2004) Plant Biochemistry. Academic Press, California.

5. Lawlor D.W. (2001) Photosynthesis in C3 and C4 Pathway.3rd Ed. Viva. New Delhi.

6. Nelson David and Cox Michael. (2007) Lehninger Principles of Biochemistry.W.H.Freeman and Company. New York.

7. Lincoln Taiz and Eduardo Zeiger (2010) Plant Physiology, 5th edition. Sinauer Associates, Inc. Publishers. Sunder land, USA

BOT-611-MJP(E) Practicals based on BOT-610-MJ(E) Advanced Plant Physiology-I (2 Credits: 15 Practicals)		**2C**
1	Measurement of chlorophyll fluorescence	**1P**
2	Measurement of relative water content in C3, C4, and CAM plants in water related conditions	**2P**
4	Determination of respiration flux through cytochrome c and AOX pathway	**1P**
5	Determination of RuBPCase activity in C3 and C4 plants	**2P**
6	Determination of PEPcase activities in C4 and CAM plants	**2P**
7	Determination of the ratio of reducing and non-reducing sugars at different stages of crop growth	**2P**
8	Comparison of growth rate and days to flowering in response to altered photoperiod / nitrogen fertilizer application / irrigation in a crop plant	**3P**
9	Estimation of neutral and acid invertase activity during grain filling in any crop species	**3P**
10	Construction of crop growth curve	**1P**
11	Comparative analysis of productivity in non-irrigated and irrigated areas	**2P**

BOT-610-MJ(F) Pharmacognosy – I (2 Credits: 30 Lectures)		2C
Credit 1: Natural product chemistry		**15L**
1	Overview of major secondary metabolite biosynthetic pathways in plants	**1L**
2	Occurrence & distribution of phenolics and flavonoids, alkaloids, tannins, terpenoids and essential oils	**3L**
3	Regulation of secondary metabolite pathways and compartmentation of these in plants	**3L**
4	Methods of extraction, purification, identification and estimation of major metabolites. Case studies	**6L**
5	High Throughput Screening (HTS)	**2L**
Credit 2: Applied Pharmacognosy		**15L**
1	Ethnobotany: Concept, relevance and classification. Methods and techniques used in ethnobotany. Ethnopharmacology and its applications.	**3L**
2	Regulatory requirements for new drugs: Biomarkers, definition, importance in crude drug standardization	**4L**
3	Standardization, quality, efficacy and safety requirements & assessment procedures for herbal medicines as per USFDA	**3L**
4	Nutraceuticals and cosmeceuticals: Introduction, classification and their formulations, botanical sources, properties and uses	**5L**

Suggested Readings:

1. Bajaj, Y.P.S., Ed. (1988) Biotechnology in Agriculture and Forestry – vol. 4, Springer-Verlag, Berlin, Heidelberg, New York, Tokyo.
2. Buchanan B. B., Gruissem W. and Jones R. L. (2015) Biochemistry and Molecular Biology of Plants. Second Edition. Wiley Blackwell.
3. Chandra S., Lata H. and Varma A. (2013) Biotechnology for Medicinal Plants. Micropropagation and Improvement. Springer-Verlag, Berlin, Heidelberg.
4. Charlwood B.V. and Rhodes M. V. Ed. (1999) Secondary products from plant tissue culture. Clarendon Press, Oxford.
5. Cseke L. J., Kirakosyan A., Kaufman P. B., Warber S., Duke J. A. and Brielman H. L. (2006) Natural Products from Plants. 2nd Edition, CRC Press, Taylor & Francis Group.
6. Das H. K. (Editor) (2007) Textbook of Biotechnology. 3rd Edition. Wiley India (P) Ltd.
7. Dewick Paul M. (2002) Medicinal Natural Products (A Biosynthetic Approach), 2nd Edition, John Wiley and Sons Ltd., England.

8. DiCosmo F. and Misawa M. (Editors) (1996), Plant Cell Culture Secondary Metabolism toward Industrial Application. CRC Press, Boca Raton, New York.
9. European Pharmacopoeia. 9th Edition. (2017). 3 Volume Set.
10. Evans W. C. (2009) Trease and Evans' Pharmacognosy. Elsevier Health Sciences.
11. Farooqi A. A. and Sreeramu B. S. (2004) Cultivation of Medicinal and Aromatic Crops. Revised Edition. Universities Press (India) Pvt. Ltd.
12. Fu T.-J., Singh G. and Curtis W. R. (2000) Plant Cell and Tissue Culture for the Production of Food Ingredients. Springer International Edition. Springer (India) Pvt. Ltd., New Delhi.
13. Greene J. J. and Rao V. B. (1998) Recombinant DNA – Principles and Methodologies. CRC Press.
14. Harborne A. J. (1998) Phytochemical Methods A Guide to Modern Techniques of Plant Analysis. Third Edition. Chapman and Hall.
15. Indian Pharmacopoeia 7th Edition (2014). 4 Volume Set.
16. Primrose S. B. and Twyman R. (2006). Principles of Gene Manipulation and Genomics. 7th Edition, Wiley-Blackwell.
17. Pushpangadan P., Nyman U. L. F., George V. (1995) Glimpses of Indian Ethanopharmacology. Tropical Botanic Garden and Research Centre Thiruvananthapuram, India and The Royal Danish School of Pharmacy, Copenhagen, Denmark..
18. Rai M. and Carpinella M. C. (2006) Naturally Occurring Bioactive Compounds. Elsevier B. V.
19. Raman N. (2006) Phytochemical Techniques. New India Publishing Agency, New Delhi, India.
20. Ramavat K. G. and Goyal Shaily (2009) Comprehensive Biotechnology. 1st Edition. S. Chand Publishing.
21. Ramawat K. G. and Merillon J-M. (Editors) (1999) Biotechnology: Secondary metabolites, Oxford IBH Publishing Co., New Delhi
22. Ramawat K. G. and Merillon J-M. (Editors) (2008) Bioactive Molecules and Medicinal Plants. Springer Verlag, Berlin, Heidelberg.
23. Schirmer, R.E., (2000), Modern Methods of Pharmaceutical Analysis, Vol. 1, 2. CRC Press, Boca Raton, Florida.
24. Sensen C. W. (Editor) (2002) Essentials of Genomics and Bioinformatics, Wiley-VCH, Germany.
25. Smith, P. M. (1976) The Chemotaxonomy of Plants. Edward Arnold, UK
26. Swain T. E. (1963) Chemical Plant Taxonomy, Academic Press, London and New York.
27. Trigiano R. N. and Gray D. J. (1999) Plant Tissue Culture Concepts and Laboratory Exercises. 2nd Edition. CRC Press, Boca Raton, New York.
28. Tyler, V. E., Brady, L. R. and Robbers J. E. (1976) Pharmacognosy, Balliere Tindall, Calcutta.
29. Vasil I. K. (Editor) (1986) Cell culture and somatic cell genetics of plants. Vol. 4. Academic Press, New York.

30. Verpoorte R. and Alferman H. W. (Editors) (2003) Metabolic engineering of plant secondary metabolites. Kluwer Academic Publishing.
31. Wagner H. and Bladt S. (1996) Plant Drug Analysis A Thin Layer Chromatography Atlas. 2nd Edition. Springer.
32. Wagner, H. and Wolff P. (Editors) (1977) New Natural Products and Plant Drugs with Pharmacological, Biological or Therapeutical Activity. Springer Verlag, Berlin, Heidelberg, New York.

BOT-611-MJP(F) Practicals based on BOT-610-MJ(F) Pharmacognosy-I (2 Credits: 15 Practicals)		**2C**
1	Identification of crude (leaf, stem, root, bark, flower, fruit) drugs with the help of macroscopic & microscopic features	**3P**
2	Estimation of percentage extractive values of crude drugs	**2P**
3	Comparative histochemical studies of crude drugs and their adulterants/ substitutes	**3P**
4	Authentication of crude drugs using Pharmacopoeias	**1P**
5	Extraction and estimation of alkaloids from medicinal plants	**2P**
6	TLC based separation and identification of phytoconstituents	**1P**
7	Extraction of essential oils from aromatic plants/ plant products	**2P**
8	Paper chromatography based separation and identification of phytoconstituents	**1P**
9	Characterization of phytopharmaceuticals by HPLC / HPTLC	**2P**
10	Profiling of plant extracts using HPTLC	**2P**

BOT-610-MJ(G) Advanced Plant Genetics and Breeding-I (2 Credits: 30 Lectures)		**2C**
Credit 1: Cytogenetics, molecular markers and its applications breeding		**15L**
1	Variation in chromosome number: Euploidy (haploids, autopolyploids, allopolyploids), aneuploids (nullisomics, monosomics, trisomics, tetrasomics). Mapping methods with aneuploids, alien addition / substitution lines	**4L**
2	Chromosome markers, banding techniques, GISH and FISH analysis	**2L**
3	PCR: Principle, types and applications	**2L**

4	Molecular markers: Types, diversity assessment, gene mapping, marker assisted selection	**4L**
5	Map based cloning, QTL identification and mapping	**3L**
Credit 2: Breeding for quality traits		**15L**
1	Heterosis and its exploitation: Concept of heterosis, inbreeding depression, estimation of heterosis	**2L**
2	Hybrid varieties: Development and evaluation of inbreds, types of male sterility, production of hybrid seeds, merits, demerits and achievements through hybrid varieties	**4L**
3	Conventional and biotechnological approaches to improve crops for: (a) Abiotic stresses – Drought and salinity (b) Biotic stresses – Disease resistance, insect resistance (c) Quality improvement - Protein and oil	 **3L** **3L** **3L**

Suggested Readings:

1. Burnham, C.R. (1962) Discussions in cytogenetics. Burgess Pub. Co., Minnesota.
2. Hartl, D.L., Jones E.W.(2001). Genetics: Principle and analysis (4th edn) Jones and Barlett Pub., USA.
3. Khush, G S (1973) Cytogenetics of Aneuploids. Academic press New York, London.
4. Lewin, B. Genes VIII. Oxford, University press. New York, USA.
5. Russel, P.J. 1998. Genetics (5th edn). The Benjamin/ Cummins Pub. Co., Inc. USA.
6. Snustad, D.P. and Simmons, M.J. ,2000. Principles of genetics (4th edn). John Wiley and Sons, Inc., USA.
7. Strickberger, M.W: Genetics (4th edn). Mcmillan Publishing Company, New York.
8. Griffiths, A.J.F and Gilbert, W.M (2nd edn). Modern genetic analysis. W.H. Freeman and Company, New york.
9. Singh, B.D.(2005). Plant breeding: principles and methods. 7th edn.
10. Allard, R.W.(1960), principles of plant breeding. John Wiley and sons, Inc., New York.
11. Chopra, V.L. (2000) Plant breeding: Theory and practice 2nd edn. Oxford & IBH Pub., Co., ltd. New Delhi.
12. Sharma, J.R. 1994. Principles and practices of plant breeding. Tata Mcgraw Hill. Pub. Co. Ltd. New Delhi.
13. Simmonds, N.W. 1979 Principles of crop improvement. Longman, London and New York.
14. VL Chopra, Plant Breeding: Theory & Practice.
15. D.Roy, Plant Breeding: Analysis & exploitation of variation. Narosa publication.
16. DK Kar & S. Haldar, Plant Breeding & Biometery.

BOT-611-MJP(G) Practicals based on BOT-610-MJ(G) Advanced Plant Genetics and Breeding -I (2 Credits: 15 Practicals)		2C
1	Analysis of induced aberrations	**3P**
2	Meiotic behaviour of auto and allopolyploids	**2P**
3	Analysis of chiasma frequency	**2P**
4	Karyotype analysis	**3P**
5	Handling data on polygenic traits for analysis of variance and covariance, partitioning of variance components, heterosis	**2P**
6	Analysis of interspecific hybrids	**3P**
7	Localization of heterochromatin region using C-banding technique	**3P**
8	Generation of mutant population and observation of agronomically important traits	**3P**
9	Testing segregating population / mutant against biotic or abiotic stress	**2P**
10	Isolation and amplification of DNA using ISSR/RAPD markers and assessment of genetic diversity	**5P**
11	Induction and assessment of polyploidy	**3P**
12	Hybridization techniques in self and cross pollinated plants	**4P**
13	*In-vitro* anther/ microspore culture	**2P**
14	Construction of genetic linkage map using Mapmaker	**2P**
15	QTL analysis using given marker scoring data	**2P**

BOT-610-MJ(H) Plant Biotechnology- I (2 Credits: 30 Lectures)		2C
Credit 1: Gene libraries, screening of recombinants and sequencing		**15L**
1	Construction of genomic and cDNA libraries: Plasmid based, cosmid, BAC, YAC libraries, full length cDNA libraries	**3L**
2	Screening of genomic and cDNA libraries: Isolation of specific genes, probe labelling, nucleic acid hybridization and detection, structure & function based screening, antibodies, PCR pooling	**3L**
3	DNA sequencing methods, overview, next generation sequencing: evolution, platforms, library preparation, data acquisition and analysis tools	**3L**
4	Genome sequencing approaches: Shotgun, clone contig, chromosome walking, use of physical map	**3L**
5	Plant whole genome sequencing: Advances in long read sequencing and applications, Hi-C sequencing, DNase I hypersensitivity	**3L**
Credit 2: Genetic transformation of plants		**15L**
1	Overview of plant transformation methods *Agrobacterium*: Ti plasmid, molecular mechanisms of transfer and integration into host plant genome, agroinfiltration for transient expression	**3L**
2	*Rhizobium rhizogenes:* Ri plasmid, hairy root induction and its applications	**2L**
3	Binary vector for functional genomics studies: virus-based vectors for transient expression, vectors for chloroplast transformation, vectors for marker-free selection, artificial microRNA mediated silencing, CRISPR vectors, Vectors for promoter analysis, subcellular localization, transactivation	**6L**
4	*In planta* transformation and analysis of transformants	**2L**
5	Screening of transformants in subsequent generations - copy number, heterozygosity and expression	**2L**

Suggested Readings:

1. Recombinant DNA – Principles and Methodologies. Greene JJ and Rao VS, Marcel Dekker, New York, 1998.

2. Principles of gene manipulation. Primrose SB, Twyman RM and Old RW, 6th Edition, Blackwell Science, Oxford, 2001

3. Differentially expressed gene in plants. Hansen and Harper, Taylor and Francis Ltd. London, 1997.

4. Engineering plants for commercial products and applications. Eds. Collins GB and Shepherd RJ, NY Acad. Of Science Publishers 1996

5. DNA markers.Eds. Caetano-Anolles and Gresshoff, Wiley-VCH Publishers, NY, 1998

6. Introduction to Bioinformatics.Attwood, T.K., Parry-Smith, DJ, Addison Wesley Longman, Harlow, Essex, 1999

7. Bioinformatics.Westhead, DR, Parish JH and Twyman, RM, BIOS Scientific Publishers Ltd., Oxford, 2003

8. Bioinformatics – Sequence and genome analysis. D.W. Mount, CBS Publishers, NewDelhi, 2003

9. Collins GB and Shepherd RJ Eds., 1996, Engineering plants for commercial products and application. NY Acad. Of Science Publishers

10. Senson CW Edt, 2002, Essentials of Genomics and Bioinformatics,. Wiley-VCH Publishers, NY.

11. Charlwood B.V. and Rhodes MV Edt. 1999, Secondary products from plant tissue culture.Clarendon Press, Oxford.

12. Dicosmo F and Misawa M, Edt 1996, Plant cell culture: Secondary metabolism towards industrial application, CRC press, Boca Raton, N.Y.

13. Ramawat K G and Merillon J M, Edt.,1999 Biotechnology: Secondary metabolites, Oxford IBH Publishing Co., New Delhi.

14. Buchanan BB, Grussem Wand Jones RL, 2000, Biochemistry and molecular biology of plants, IK International Pvt Ltd. New Delhi.

15. Verapoorte R and Alferman HW Eds, 2002 Metabolic engineering of plant secondary metabolites. Kluwar Academic Publ., Netherlands.

BOT-611-MJP(H) Practicals based on BOT-610-MJ(H) Plant Biotechnology- I (2 Credits: 15 Practicals)		**2C**
1	Transformation of *Agrobacterium tumefaciens* with binary vector using freeze thaw method and selection for transformants	**2P**
2	Transformation of plant tissues using *Agrobacterium tumefaciens* based vectors	**3P**

3	Detection of transformants using GUS/GFP/gene specific PCR	**3P**
4	Construction of vector for functional genomics studies	**3P**
5	Basic linux commands for handling next generation sequencing data	**2P**
6	Next generation sequencing file formats, quality control and removal of low-quality reads	**2P**
7	*Agrobacterium*-mediated transient expression in *Nicotiana benthamiana* for scorable /visible markers	**4P**
8	Induction of transgenic hairy roots in medicinal plants and characterization of transgene	**4P**
SEMESTER IV: CORE COURSES (Mandatory)		
BOT-651-MJ Bioinformatics and Biostatistics (2 Credits: 30 Lectures)		**2C**
Credit 1: Basic and structural bioinformatics		**15L**
1	Introduction to databases and retrieving information from databases: Nucleotide, protein sequence and genome databases	**1L**
2	Sequence similarities, pairwise comparison of DNA and protein sequences, dynamic programming algorithms, FASTA and BLAST	**2L**
3	Multiple sequence alignments, progressive methods, iterative methods, localized alignments	**2L**
4	Determining phylogenetic relationships using DNA and protein sequences	**2L**
5	Protein structures, Ramachandran plot, protein folding	**3L**
6	Protein structure function relationship, conformational energy calculations	**1L**
7	Protein structure predictions, secondary and tertiary	**1L**
8	Protein structure modelling: homology modelling, protein threading, *ab initio/de novo* modelling, artificial intelligence for protein modelling	**3L**
Credit 2: Biostatistics		**15L**
1	Descriptive statistics: Populations and samples, graphical presentation of data frequency distribution, central tendency and dispersion: Mean, median, variance standard deviation	**2L**

2	Sampling distributions, standard error of mean	**1L**
3	Normal distribution, standardised normal distribution (z), attributes of normal distributions, Student's t distribution, estimation and confidence interval	**2L**
4	Hypothesis testing, type I and type II errors	**1L**
5	Binomial and Poisson distribution	**1L**
6	Non-parametric tests	**1L**
7	Experimental designs- completely randomised, randomised block and factorial experimental designs	**2L**
8	Test of homogeneity, analysis of variance, *post hoc* tests	**2L**
9	Correlation and regression, linear and non-linear regression	**2L**
10	Chi-square test for goodness of fit and independence	**1L**

Suggested Readings:

1. Statistical Methods – Snedecor G.W. and Cochran W.G. Affiliated East-West Press Pvt. Ltd. 1989

2. Statistical methods in Agriculture and Experimental Biology – Mead, R. and Curnow, R.N. Chapman and Hall, 1983

3. Practical statistics and experimental design for plant and crop science – Clewer, A.G. and

Scarisbrick, A.H., John Wiley, New York, 2001

4. Bioinformatics - Westhead, DR, Parish JH and Twyman, RM, BIOS Scientific Publishers Ltd., Oxford, 2003

5. Bioinformatics and Molecular Evolution – Higgs PG and Attwood TK, Blackwell Publishing, Oxford, UK, 2005

6. Bioinformatics A Practical Guide to the Analysis of Genes and Proteins- Baxevanis A. D.,

Francis Ouellette B. F. John Wiley & sons Inc., 2001

7. Bioinformatics and Functional Genomics, 3rd Edition Jonathan Pevsner 2015 Wiley-Blackwell

8. Structural Bioinformatics, 2nd Edition Jenny Gu, Philip E. Bourne 2009 Wiley-Blackwell

BOT-652-MJ Plant Evolution (2 Credits: 30 Lectures)		2C
Credit 1 Concepts of evolution		**15L**
1	Evolutionary theories - Lamarckism, Darwinism, concepts of variation, adaptation, struggle for fitness: natural selection & mutations, Neo-Lamarckism, Neo-Darwinism	**4L**
2	Origin of cells and unicellular evolution - Origin of basic biological molecules, abiotic synthesis of organic monomers and polymers, concepts of Oparin and Halden, Miller's experiment, origin and evolution of prokaryotic and eukaryotic cells, anaerobic metabolism, photosynthesis and aerobic metabolism	**5L**
3	Paleontology and evolutionary history - The geological time scale, major evolutionary events	**1L**
4	Study of major groups of fossil plants with reference to evolutionary history and general characters- Psilopsida, Lycopsida, Sphenopsida, Pteropsida, Progymnospermopsida, Gymnospermopsida	**5L**
Credit 2		**15L**
1	Origin of Angiosperms: Monophyletic or Polyphyletic, Pteridosperms theory, Bennettitalean theory, Gnetalean theory	**5L**
2	The mechanisms of evolution: Natural selection, migration and random genetic drift, adaptive radiation and modification, isolation mechanisms, speciation, allopatric and sympatric, convergent evolution, sexual selection, co-evolution	**5L**
3	Molecular evolution: origin of new genes and proteins, gene duplication and divergence, molecular divergence and molecular clocks, molecular phylogeny,	**5L**

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Biswas C and Johari B.M 2004. The Gymnosperms Narosa Publishing House, New Delhi. 497 pp.

Chamberlain C.J 1934. Gymnosperms-Structure and Evolution, Chicago.

Cronquist, A. 1968. The Evolution and Classification of Flowering Plants. Thomas Nel and Sons, Ltd. London.

De Robertis and De Robertis (2005). (8th edition) (Indian) Cell and Molecular Biology, Lippincott Williams, Philadelphia. [B.I Publications Pvt. Ltd. New Delhi].

Lodish S., Baltimore B., Bek C., Lawrence K. (1995).Molecular Cell Biology. 3 rd Edn. Scientific American Books, New York.

Stewart W.N. and Rathwell G.W. 1993. Paleobotany and the Evolution of plants. Cambridge University Press.

Verma P.S and Agarwal V.K. (2006) Cell Biology, Genetics, Molecular Biology, Evolution, Ecology. S.Chand and Company, New Delhi.

BOT-653-MJ Tools and Techniques in Botany-II (2 Credits: 30 Lectures)		**2C**
Credit 1		**15L**
1	**Spectroscopic techniques:** Visible, UV, IR spectrophotometry, spectrofluorimetry, NMR spectroscopy, circular dichroism, atomic absorption and mass spectrometry, MALDI-TOF, flow cytometry	**9L**
2	**Electrophoretic techniques:** Supports, electroendosmosis, electrophoresis (native with activity staining, dissociating and denaturing conditions), isoelectric focusing, 2-D electrophoresis, staining	**6L**
Credit 2		**15L**
1	**Chromatographic techniques:** Paper, thin layer and column chromatography, gel filtration, ion exchange and affinity chromatography, high pressure liquid chromatography, gas chromatography	**8L**
2	**Immunological techniques:** Immune response, antibodies and their specificity, antigen-antibody interactions, immunodiffusion and immunoelectrophoresis techniques, immunoassays	**7L**

References

1. David L. Nelson, Michael M. Cox Lehninger Principles of Biochemistry; W. H. Freeman 7th edition edition 2017.

2. David M Freifelder Physical Biochemistry: Applications to Biochemistry and Molecular Biology (Life Sciences/Biochemistry, W. H. Freeman; 2nd Revised edition, 1983.

3. Jeremy M. Berg, John L. Tymoczko, Lubert Stryer Biochemistry, W. H. Freeman; 7th edition edition 2011.

4. Keith Wilson, John Walker, "Practical Biochemistry Principles and Techniques" Cambridge University Press 2010.

5. S. M. Khasim, “Botanical Microtechnique: Principles and Practice”. Capital Publishing Company. 2002.

6. Thomas J. Kindt, Barbara A. Osborne and Richard Goldsby “Kuby Immunology” .W.H. Freeman; 6th edition edition 2006.

7. Allen, James P. Biophysical chemistry. Wiley-Blackwell; 2008.

8. Peter Jomo Walla, Modern Biophysical Chemistry. Wiley-VCH Verlag GmbH & Co. KGaA; 2014.

9. Donald L. Pavia, Gary M. Lampman, George S. Kriz; Introduction to Spectroscopy

10. Neil E. Jacobsen, NMR Spectroscopy Explained: Simplified Theory, Applications and Examples for Organic Chemistry and Structural Biology, John Wiley & Sons, Inc.; 2007.

BOT-654-MJ Biodiversity, conservation & utilization (2 Credits: 30 Lectures)		**2C**
Credit 1 Concepts and types		**15L**
1	**Biological diversity**: Introduction, mega diversity countries, magnitude of biodiversity, direct, indirect and ethical values of biodiversity, loss of biodiversity, reasons for loss of biodiversity, taxonomic initiatives, Systematic Agenda 2020	**3L**
2	**Genetic diversity**: Nature and origin of genetic variations (within and between populations), assessment of genetic diversity - molecular approaches to plant diversity assessment based on allozymes and DNA based markers	**4L**
3	**Species diversity:** Phytogeographic and floristic patterns of species diversity, centers of species diversity, spatial patterns of species diversity	**3L**
4	**Ecosystem diversity:** Plant diversity within and between ecosystems in Indian subcontinent. Agro-biodiversity - domestication and distribution of cultivated species with respect to agro climatic zones. Diversity in domesticated species	**3L**
5	Endemism, hotspots, categories of IUCN, Keystone and Flagship species	**2L**
Credit 2 Biodiversity assessment and conservation		**15L**
1	**Methods of assessment of species diversity:** Diversity indices - species richness, species abundance. CAMP exercise - objectives and procedure, remote sensing & ground truthing	**2L**
2	**Organizations associated with Biodiversity management**: UNEP, WWF, FAO, WCMC, CBD, IPR, CITES, Ramsar convention, International Undertaking on Plant Genetic resources and Farmers Rights, MoEFCC	**3L**

3	**Strategies of sustainable utilization**: Plant genetic resources and sustainable utilization	**2L**
4	**Conservation strategies:** Sacred Groves, Sthalavrikshas, People's movement for biodiversity conservation, Chipko movement, etc. Organizations involved in conservations, IEC activities taken by government	**2L**
5	***In-situ* conservation**: Protected areas, biosphere reserves and national parks ***Ex-situ* conservation:** Germplasm collections, Botanic gardens, seed banks, pollen banks, field gene banks, DNA banks, *In-vitro* conservation methods	**4L**
6	Acts and Public notices related to biodiversity, People's Biodiversity Register (PBR), IKS	**2L**

References

1. Avise JC (1994) Molecular Markers, Natural History and Evolution, Chapman & Hall, London
2. Barbier EB, Burgess JC & Folke C. (1994) Paradise Lost? The Ecological Economics of Biodiversity; Earthscan, London
3. Bowles M.L. & Whelan C.J. (1996) Restoration of Endangered Species; Cambridge Univ. Press.
4. Bowles M.L. & Whelan C.J. (Eds.) (1996) Restoration of Endangered Species; Cambridge Univ. Press.
5. Dwivedi O.P (1994), Environmental Ethics; Sanchar Publishing House, New Delhi
6. EDavid Hill, Matthew Fasham, Graham Tucker, Michael Shewry & Philip Shaw (Eds.) (2004) Handbook of Biodiversity Methods – Survey, Evaluation and Monitoring ; Cambridge
7. Foster, M. G. Mueller and Bills G. (2004) Biodiversity of fungi : Inventory and Monitoring methods Academic Press. 777ppp
8. Gadgil M. & Guha R. (1992) This Fissured Land: An Ecological History of India; Oxford University Press, New Delhi
9. Hajra P.K. & V. Mudgal (Eds.) (1997) Plant Diversity Hotspots in India – An Overview, BSI
10. Handbook of the Convention on Biological Diversity (2001), Secretariat of the Convention on Biological Diversity. Earthscan publ., London
11. Heywood and Watson (Edt.) (1995) Global Biodiversity Assessment, UNEP, Cambridge University Press.
12. Hunter –Cevera , J.C. and Angella Belt (1996) Maintaining cultures for Biotechnology and Industry.
13. Kothari, Ashish (1997) Understanding Biodiversity- Life, sustainability and Equity; Orient Longman
14. Krishnamurthy K.V. (2003) An Advanced Textbook on Biodiversity-Principles and Practice, Oxford & IBH Publ. New Delhi
15. Magurran Anne (1988) Ecological Diversity & Its Measurement, Chapman & Hall India
16. Michael J. Jeffries (2005) Biodiversity and Conservation, Routledge, London

17. Michael P. (1984) Ecological Methods for field & Laboratory investigations, TMH Co. ltd. Bombay.
18. N.K. Uberoi (2003) Environmental Management, Excel Books, New Delhi
19. Ninan K.N. (2007) The Economics of Biodiversity Conservation, Earthscan, London
20. Paroda R S and Arora R K (1991) Plant Genetic Resources: Conservation and Management, IBPGR, India
21. Razdan M K and Cocking E C (1997) Conservation of Plant Genetic Resources *In Vitro*, Volume 1, Oxford & IBH Pub.
22. Shailaja Ravindranath & Sudha Premnath (1997) Biomass Studies – Field Methods for Monitoring Biomass, Oxford & IBH, New Delhi.
23. Singh J S, Singh S P and Gupta S R (2006) Ecology Environment and Resource Conservation, Anamaya Publishers
24. T.V. Ramchandra, R. kiran, N. Ahalya (2002) Status, Conservation & Management of Wetlands, Allied Publ. New Delhi.
25. Uma Shaanker, R. Ganeshiah, KN. & Bawa KS (Eds) (2001) Forest Genetic Resources: Status, Threats and Conservation Strategies; Oxford & IBH, New Delhi
26. WCMC (1992) Global Biodiversity: Status of the Worlds Living Resources; Chapman and Hall, London
27. William J. Sutherland (1997) Ecological Census Techniques – A Handbook. Cambridge Uni. Press.
28. WRI/IUCN/UNEP (1992) Global Biodiversity Strategy: Guidelines for Action to Save, Study, and Use Earth's Biotic Wealth Sustainably and Equitably; WRI Publ, Baltimore, MD.

BOT-655-MJP Practicals based on BOT-651 Bioinformatics and Biostatistics and BOT-652-MJ Plant Evolution (2 Credits: 15 Practicals)		**2C**
Practicals based Bioinformatics (Any 5P)		
1	Data retrieval of nucleotide, protein and genome sequences from databases	**2P**
2	Pairwise comparison of DNA and protein sequences - BLAST	**2P**
3	Multiple sequence alignments: progressive & iterative methods	**2P**
4	Determining phylogenetic relationships using DNA and protein sequences	**2P**
5	Visualizing protein 3D structure	**1P**
6	Prediction of 3D structure of proteins using homology modelling	**2P**

Practicals based Biostatistics (Any 5P)		
1	Data, graphical presentation of data – frequency distribution, Sample means and standard deviations, confidence intervals	**2P**
2	Hypothesis testing-comparison of means	**2P**
3	Analysis of variance	**2P**
4	Correlation and regression	**2P**
5	Binomial distribution	**2P**
6	Non-parametric test	**2P**
Practicals based on Plant Evolution- II (Any 5P)		
1	Study of available fossils of Psilopsida, Lycopsida, Sphenopsida, Progymnospermopsida and Gymnospermopsida	**3P**
2	Study of available fossils of Angiosperms	**1P**
3	Construction of phylogenetic tree to trace plant evolution	**1P**
4	Comparative morpho-anatomical analysis of vegetative and reproductive structures	**2P**
5	Computational analysis of gene duplication and divergence	**2P**

BOT-656-MJP Practicals based on BOT-653-MJ Tools and Techniques in Botany-II and BOT-654-MJ Biodiversity, conservation & utilization (2 Credits: 15 Practicals)		**2C**
Practicals based on Tools and Techniques in Botany-II (Any 8P)		
1	Extraction and separation of plant pigments by thin layer chromatography	**2P**
2	Derivatization and separation of amino acids/ fatty acids using TLC	**2P**
3	Ouchterlony immunodiffusion technique for testing specificity of antigens and antibodies	**2P**
4	Separation of protein using gel filtration/ affinity / ion exchange chromatography	**2P**
5	Demonstration of Spectrofluorimetry	**1P**
6	Demonstration of HPLC and quantification of analyte	**2P**

7	Demonstration of GC-MS and quantification of analyte	**2P**
8	Separation of enzyme isoforms using native PAGE and activity staining	**3P**
Practicals based on biodiversity, conservation & utilization (Any 7P)		
1	Biodiversity assessment by line transect and quadrat method	**2P**
2	Inventory and estimation of plant species richness	**2P**
3	Estimation of biomass of grassland/ woody vegetation	**2P**
4	To study floral and faunal diversity	**2P**
5	Propagation of any two threatened plant species through asexual and sexual methods	**2P**
6	Assessment of vegetation by using GIS	**1P**

BOT-660-MJ(A) Advanced Phycology-II (2 Credits: 30 Lectures)		**2C**
Credit 1		**15L**
1	Cultivation of microalgae: Sampling methods, nutrient media, isolation techniques, role of physical and chemical factors on growth kinetics and measurements	**3L**
2	Scaling-up, harvesting and drying of algal biomass, continuous cultures	**2L**
3	Photobioreactors (closed system) for mass production of microalgae: Principle considerations and designing, tubular and flat-plate reactors, merits and demerits	**2L**
4	Mariculture of seaweeds: Necessity and principles, cultivation of economically important *Porphyra*, *Gracilaria*, *Kappaphycus*, *Laminaria*	**2L**
5	Conservation strategies for algae: Role of genetic resource centers and culture collections, methodologies	**3L**
6	Algal genomics and metabolic engineering: Biofuel production, lipid enhancement	**3L**

Credit 2		
1	Eutrophication: Causes, chemical and biological responses of eutrophication, Production of toxic metabolites from bloom forming algae and their consequences on aquatic environments and trophic level	**4L**
2	Phycoremediation by High Rate Algal Ponds (HRAPs)	**2L**
3	Secondary metabolites from microalgae and their biosynthesis, Inducibility of defense metabolites against herbivores in microalgae, *Microcystis-Daphnia* interaction: a case study	**5L**
4	Grazer's impact on seaweeds and seaweed communities, seaweed defenses against grazers	**4L**

References

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2. Barsanti, L. and Gualtieri, P. (2006). Algae: anatomy, biochemistry and biotechnology. CRC Press, pp. 301.

3. Benson, E. E. (ed.) (1999). Plant conservation biotechnology. Taylor & Francis, pp. 309.

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9. Gonzalez-Fernandez, C. and Munoz, R. (eds.) (2017). Microalgae-based biofuels and bioproducts. Woodhead Publishing, UK. Pp. 540.

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22. Upadhyay, S. K. and Singh, S. P.(eds). (2021). Bioprospecting of plant biodiversity for industrial molecules. John Wiley & Sons Ltd., UK. Pp. 431.

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BOT-661-MJP(A) Practicals Based on BOT-660-MJ(A) Advanced Phycology-II (2 Credits: 15 Practicals)		**2C**
1	Preparation of nutrient media for growing algal cultures	**1P**
2	Collection, isolation, purification and maintenance of microalgae	**4P**
3	Small scale biomass production of selected microalgae	**2P**

4	Extraction of lipids from algal biomass	**2P**
5	Separation and quantification of algal TAG/lipid using HPTLC	**2P**
6	Study of algal biodiesel properties	**2P**
7	Biphasic culturing of N_2-fixing soil algae	**2P**
8	Immobilization of microalgae for bioprospecting	**1P**
9	Extraction of agar-agar/alginates from seaweeds	**2P**
10	Preparation of seaweed liquid fertilizer and its effect on seedling growth	**3P**
11	Enrichment of algal cultures for mass production	**2P**
12	Determination of carotenoids/phycobiliproteins in microalgae	**1P**
13	Measurement of photosynthesis in microalgae	**1P**
14	Determination of microalgal cell counts	**1P**
15	Algal growth measurements and growth curve studies	**3P**
16	Lyophilization, reculturing and viability testing of microalgae	**2P**
17	Identification of bloom causing algae	**2P**
18	Visit to algal cultivation pond/institute/industry	**2P**
19	Primer designing and PCR based amplification of secondary metabolite pathway gene/s	**4P**

BOT-660-MJ(B) Advanced Mycology-II (2 Credits: 30 Lectures)		2C
Credit: 1 Metabolic engineering and bioprospecting of fungi		**15L**
1	Secondary metabolites in fungi: Types, biosynthetic pathways, significance and medicinal importance	**2L**
2	Fungal genomics to understand biosynthetic gene clusters (BGCs)	**1L**
3	Metabolic engineering in fungi to produce secondary metabolites	**4L**
4	Endophytic fungi and their role in plants and in therapeutics	**2L**
5	Medicinal mushrooms: Active principles in *Ganoderma lucidum, Cordyceps, Innonotus, Tremetes* etc.	**2L**
6	Production of fungal biomass for industrially important biomolecules	**2L**
7	Lichens: Overview, secondary metabolites and their biosynthetic pathways	**2L**
Credit:2 Fungi in food and food industries		**15L**
1	Fungi as food: Mushrooms and other edible fungi, fungi in food web, cell and mycelium as food, fermented products, nutraceuticals	**5L**
2	Application of fungi in food and beverages industry, industrially important fungal enzymes	**5L**
3	Fungi and food spoilage: Types, factors responsible for spoilage and control measures	**5L**

References

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Gupta, R and Mukerji, K. G. 2001 Microbial Technology A. P. H. Publishing Coprporation, New delhi.

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Vijay kumar Gupta, Robert L. Mach, S. Sreenivasaprasad. Fungal Biomolecules – sources, Applications and Recent developments by 2015, Published by John Wiley & Sons. ltd.

BOT-661-MJP(B) Practicals based on BOT-660-MJ(B) Advanced Mycology-II (2 Credits: 15 Practicals)		**2C**
1	Introduction and data retrieval from fungal databases	**1P**
2	Retrieval of fungal genome data and identification of secondary metabolites gene cluster using antiSMASH (fungi) webserver	**2P**
3	Isolation of endophytic fungi and determination of antimicrobial activity	**3P**
4	Detection of secondary metabolites from lichen thalli	**2P**
5	Study the various medicinal mushrooms and determining their bioactivity	**3P**
6	Production of alcohol/ other products by fermentation technique	**2P**
7	Visit to the fungal research laboratory/ industry	**2P**
8	Preparation of fungal wet/ dried herbarium specimens	**1P**
9	Primer designing and PCR based amplification of secondary metabolite pathway gene/s	**4P**

BOT-660-MJ(C) Angiosperms systematics-II (2 Credits: 30 Lectures)		2C
Credit 1: Systematics		**15L**
1	**Systematics**: Overview, Sources of data - morphology, micromorphology, anatomy, embryology, palynology, biochemistry, karyology, sequence data etc.	7L
2	**Biosystematics**: Aims, concepts, methods, categories - ecotype, ecospecies, cenospecies, comparium, ecotypic variations and taxonomy, scope and limitations	3L
3	**Taxometrics**: Principles, methodology, merits and demerits	2L
4	**Cladistics**: Principles, cladistic approach in plant classification, methodology, merits and demerits	3L
Credit 2: Molecular aspects and APG IV		15L
1	**DNA based markers**: Introduction to hybridization and PCR based markers - RFLP, RAPD, AFLP, SSR, SNP, sequence-based polymorphism	2L
2	Determining genetic relatedness using DNA based markers- Phylogenetic tree construction using distance based (UPGMA, Neighbour joining) and character based (Maximum Likelihood, Maximum Parsimony, Bayesian analysis) methods. DNA barcoding, phylogenetic relationships and taxonomic disputes	3L
3	**Major clades in APG:** Morphological variations, systematic position, interrelationships, phylogeny and economic importance of following families: ANA Grade: Amborellaceae, Magnoliids: Myristicaceae, Annonaceae; Monocots: Orchidaceae, Pandanaceae, Poaceae; Eudicots: Papaveraceae, Core Eudicots: Dilleniaceae; Superrosids: Haloragaceae; Rosids-I: Moraceae, Euphorbiaceae; Rosids-II: Geraniaceae, Myrtaceae; Superasterids: Polygonaceae; Euasterid-I: Molluginaceae, Euasterid-II: Pittosporaceae.	10L
Recommended Books and Websites		

23. Angiosperm Phylogeny Group (2016) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society* 181: 1–20.
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35. Singh, Gurcharan. 2004. Plant Systematics: Theory and practice Oxford and YBH Publishing Co. Pvt. Ltd., New Delhi.
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42. Walter S. Judd, Christopher S. Campbell, Elizabeth A. Kellogg, Peter F. Stevens and Michael J. Donoghue. 2007. Plant Systematics: A Phylogenetic Approach, Third Edition. Sinauer Associates, Inc., Publishers, Sunderland, USA.

BOT-661-MJP(C) Practicals based on BOT-660-MJ(C) Angiosperms systematics- II (2 Credits: 15 Practicals)		**2C**
1	Micromorphology, anatomy, palynology and karyology features used for classification	**4P**
2	Identification of genera and species of various clades as per APG IV (any 20 species)	**5P**

3	Study of characters of anemophilous, hydrophilous, cheiropterophilous, entomophilous flowers	**2P**
4	Exercises on nomenclature problems	**2P**
5	Exercise on numerical taxonomy	**1P**
6	DNA isolation, PCR and phylogenetic tree construction	**4P**
7	Study of fossil angiosperms	**2P**
8	Field visit to nearby forest areas/ institutes	**4P**

BOT-660-MJ(D): Plant Ecology – II (2 Credits: 30 Lectures)		**2C**
Credit 1: Landscape Ecology		**15L**
1	Introduction, principles, scale concepts and hierarchy theory	**3L**
2	Landscape heterogeneity and dynamics, pattern analysis, data generation through GIS and metrics, spatial analysis	**3L**
3	Landscape models and disturbance dynamics	**2L**
4	Landscape connectivity and its effects on individual movement and dispersal	**3L**
5	Landscape effects on population distributions and dynamics, population genetic, community and ecosystem structure	**2L**
6	Applications: Forest management, regional risk assessment, continental-scale monitoring	**2L**
Credit 2: Bioremediation mechanisms		**15L**
1	Biomonitoring of contaminated ecosystems	**1L**
2	Decontamination practices: chemical, physical and biological	**2L**
3	Microbial systems: Aerobic and anaerobic degradation of the wastes	**3L**
4	Solid waste management practices, composting and biogas production	**3L**
5	Mechanisms of phytoremediation: Phytoextraction, Phytostabilization, Phytoaccumulation and Phytovolatilization, Phycoremediation	**3L**

6	Heavy metal stress and its management	**3L**

Suggested Readings:

1. Begon, M., Townsend, C. R. and Harper, J. L. (2005). *Ecology: From individuals to Ecosystems* 4th edition, Wiley-Blackwell.

2. Odum, E. P. (2007) *Fundamentals of Ecology*, 5th edition, Thomson books.

3. Coleman, D.C., Crossley, D. A. and Handrix, P. F (2004) *Fundamentals of Soil Ecology*, 2ndedition, Elsevier academic press.

4. Ambhast, R. S. (1998) *A Text Book of Plant Ecology*, 9th edition, Friend and Co.

5. Canter L (1996) *Environmental Impact Assessment*, 2nd Edition, McGraw Hill Publishing Company.

6. Gurevitch, J., Scheiner, S. M. and Fox, G. A. (2006) *TheEcology of Plants*, Sinauer Associates.

7. Hynes, H. B. N. (1978) *Biology of Polluted Water*, 1st edition, Liverpool University Press.

8. Sutherland, W. J. (Ed.). (2006). *Ecological Census Techniques: AHandbook*. Cambridge University Press.

9. Mittelbach, G. G., & McGill, B. J. (2019). *Community Ecology*. Oxford University Press.

10. Trewavas, A. (2014). *Plant Behaviour and Intelligence*. OUP Oxford.

11. Wohlleben, P. (2016). *The hidden life of trees: What they feel, how they communicate—Discoveries from a secret world* (Vol. 1). Greystone Books.

12.Schulze, E. D., Beck, E,, Buchmann, N,, Clemens, S,, Müller-Hohenstein, K. and Scherer-Lorenzen (2019). *Plant Ecology*. Springer

13. Misra R and Puri GS (2018). *Indian Manual of Plant Ecology*. Scientific Publishers (India)

14. Jose, S., Singh, H. P., Batish D. R. and Kohli, R.K. (2013). *Invasive Plant Ecology*. CRC Press.

15. Pugnaire, F.I. andValladares, F. (2007). *Functional Plant Ecology*. CRC Press

16.Hasanuzzaman, M., Fujita, M., Oku, H, andTofazzal Islam, M. (2019). *Plant Tolerance to Environmental Stress*. CRC Press

17. Dighton, J. (2018). *Fungi in Ecosystem Processes*. CRC Press

18. Cronk, J. K. and Siobhan Fennessy, M. (2001). *Wetland Plants*. CRC Press

19. Lemon, E. R. (2019). *CO2 and Plants*. The Response of Plants to Rising Levels of Atmospheric Carbon Dioxide. CRC Press

20. Davet, P. (2004). Microbial Ecology of Soil and Plant Growth. CRC Press

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BOT-661-MJP(D) Practicals based on BOT-660-MJ(D) Plant Ecology – II (2 Credits: 15 Practicals)		**2C**
1	Preparation of landscape map based on topography	**2P**
2	Measuring vegetation of landscape through stratified random sampling	**3P**
3	Monitoring landscape dynamics through GIS data	**2P**
4	Studying soil respiration responses at different elevations	**2P**
5	Isolation of soil borne microbes and decomposition	**3P**
6	Analysis of texture and water holding capacity of soil	**2P**
7	Studying phytoremediation potential of plants grown in polluted areas	**2P**
8	Visit to different landscape areas and preparation of report	**2P**
9	Visit to different restoration sites and preparation of report	**2P**

BOT-660-MJ(E) Advanced Plant Physiology-II (2 Credits: 30 Lectures)		**2C**
Credit 1: Abiotic stresses		**15L**
1	**Water stress** - Effects on growth and metabolism in plants. Acclimation responses to water stress at physiological and molecular level, stress signaling. Avoidance, escape and tolerance	**5L**
2	**Salinity stress** - Osmotic and ionic effects on growth and metabolism, acclimation responses to salinity stress at physiological and molecular level, stress signaling.	**5L**
3	**Temperature stress** - Effects on growth and metabolism. Adaptive responses of plants to low and high temperature stress	**3L**
4	**Heavy metal stress -** Effects on growth and metabolism, strategies of heavy metal tolerance	**2L**
Credit II: Biotic stresses		**15L**

1	**Plants interacting with herbivores** - Plant immunity responses, plants defense mechanisms, defense signaling pathways, hormonal cross-talk, growth defense trade-off,	**6L**
2	**Plants interacting with pathogens -** Plant immunity responses, Flor's Gene for Gene hypothesis, plants defense mechanisms, defense signaling pathways, hormonal cross-talk, growth defense trade-off	**7L**
3	**Plants' responses against plant parasites -** hemiparasites and holoparasite, intra kingdom parasitism mechanisms	**2L**

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2. Pessarakli, M. (Ed.). (2021). *Handbook of plant and crop physiology*. CRC press.

3. Rao, N. S., Shivashankara, K. S., & Laxman, R. H. (Eds.). (2016). *Abiotic stress physiology of horticultural crops* (Vol. 311). India: Springer.

4. Rout, G. R., & Das, A. B. (Eds.). (2013). *Molecular stress physiology of plants*. Springer Science & Business Media.

5. Rao, K. M., Raghavendra, A. S., & Reddy, K. J. (Eds.). (2006). *Physiology and molecular biology of stress tolerance in plants*. Springer Science & Business Media.

6. Hossain, A. (Ed.). (2021). *Plant stress physiology*. BoD–Books on Demand.

BOT-661-MJP(E) Practicals based on BOT-660-MJ(E) Advanced Plant Physiology – II (2 Credits: 15 Practicals)		**2C**
1	Study of transpiration and stomatal physiology under abiotic stress	**2P**
2	ysiological effect of water/ salinity stress on crop plant/s	**2P**
3	Studies on superoxide dismutase/ catalase/ peroxidase activity in response to drought/ salinity/ heavy metal/ pathogen application	**2P**
4	Effect of abiotic/ biotic stress priming agent on plant growth	**3P**
5	Determining the effect of drought on accumulation of abscisic acid	**3P**
6	Determining the effect of heat stress on activity of RuBPCase	**2P**
7	Studies on depletion of mineral elements from media and accumulation in *in vitro* cultured plant tissues using Atomic absorption spectrometry	**2P**

8	*In situ* localization of superoxide and hydrogen peroxide in pathogen tolerant and susceptible genotypes in response to pathogen application	**2P**
9	Effect of herbivory on plant growth and accumulation of defense molecules	**4P**
10	Determining the expression of stress/ defense-responsive genes	**4P**

BOT-660-MJ(F): Pharmacognosy – II (2 Credits: 30 Lectures)		**2C**
Credit I: Biotechnological approaches for phytochemicals production		**15L**
1	Micropropagation of medicinal plants- culture media, explants, incubation conditions, stages of micropropagation, acclimatization and field trials	**2L**
2	Organized growth in cultures: using pre-existing meristems, organogenesis and embryogenesis	**2L**
3	Types of culture systems used for secondary metabolite production	**2L**
4	Screening and selection of high secondary metabolite producing cell lines	**1L**
5	Manipulations of secondary metabolite production in cultures a. Manipulation of culture media b. Immobilization of cells c. Elicitation using biotic and abiotic elicitors d. Biotransformation e. Precursors	**5L**
6	Scaling up and use of Bioreactors a. Strategies used for mass cultivation for hyper-production of secondary metabolites b. Types of bioreactors	**3L**
Credit II: Phytochemicals screening, activity and management		**15L**
1	Overview of chemical and biological activities of plant drugs reported in literature	**2L**
2	Pharmacological screening methods of drugs: Antimicrobial, anticancer, antidiabetic and antimalarial- mechanism of action and properties	**6L**
3	Import and export scenario of medicinal plants / crude drugs	**3L**
4	Intellectual property right (IPR) in relation to pharmacognosy	**4L**
References		

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25. Schirmer, R.E., (2000), Modern Methods of Pharmaceutical Analysis, Vol. 1, 2. CRC Press, Boca Raton, Florida.

26. Sensen C. W. (Editor) (2002) Essentials of Genomics and Bioinformatics, Wiley-VCH, Germany.
27. Smith, P. M. (1976) The Chemotaxonomy of Plants. Edward Arnold, UK
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BOT-661-MJP(F) Practicals based on BOT-660-MJ(F) Pharmacognosy II (2 Credits: 15 Practicals)		**2C**
1	Micropropagation of a plant through multiplication of pre-existing meristems	**3P**
2	Micropropagation of a plant through organogenesis	**4P**
3	Initiation of callus culture, detection and estimation of alkaloids	**4P**
4	Initiation of root/ hairy root culture, detection and estimation of alkaloids	**4P**
5	Study of growth and secondary metabolite production in cell suspension cultures	**3P**
6	Elicitation of plant cells for enhancement of secondary metabolites	**2P**
7	Antibacterial screening of herbal drugs / extracts	**2P**
8	Antifungal screening of herbal drugs / extracts	**2P**
9	Anticancer activity of herbal drugs / extracts by MTT assay	**2P**
10	Antioxidant activity of herbal drugs/extracts	**1P**

BOT-660-MJ(G): Advanced Plant Genetics and Breeding-II (2 Credits: 30 Lectures)		**2C**
Credit 1: Functional genomics		**15L**
1	Introduction to functional genomics, relationship of genotype and phenotype, reverse genetics and forward genetics	**1L**
2	Expression profiling approaches: DDRT-PCR, cDNA-AFLP, SSH, SAGE, Microarray, NGS	**6L**

3	Reverse genetic tools for understanding gene functions: Gene silencing by RNA interference (RNAi), artificial microRNA, VIGS	**3L**
4	Insertional mutagenesis: T-DNA and transposon mediated mutagenesis, TILLING	**2L**
5	Genome editing for targeted improvement of plants: Engineered meganucleases (EMNs), zinc finger nucleases (ZFNs), transcription activator-like effector nuclease (TALENs)	**3L**
Credit 2: Advances in genome editing and sequencing		**15L**
1	**CRISPR-Cas based editing**: Introduction, CRISPR and Cas types, modifications of Cas, guide RNA designing, cloning vectors and methods	**3L**
2	**CRISPR-Cas applications**: knock-out, knock-in, promoter studies, large genomic deletions, localization studies, etc.	**4L**
3	**Long read sequencing platforms**: ONT, PacBio, methodology, library preparation, applications- genome sequencing, RNAseq, transcriptome analysis, resequencing, variant calling, structural variant analysis, epigenetics	**6L**
4	**Biosafety concerns and regulations regarding transgenic crops**: Biosafety concerns with transgenic crops, gene containment, safer selectable markers and strategies to remove antibiotic resistance markers from transformed plants	**2L**

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7. Strickberger, M.W: Genetics (4th edn). Mcmillan Publishing Company, New York.
8. Griffiths, A.J.F and Gilbert, W.M (2nd edn). Modern genetic analysis. W.H. Freeman and Company, New york.
9. Singh, B.D.(2005). Plant breeding: principles and methods. 7th edn.
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BOT-661-MJP(G) Practicals based on BOT-660-MJ(G) Advanced Plant Genetics and Breeding-II (2 Credits: 15 Practicals)		**2C**
1	RNA isolation, purification, quantification, electrophoresis of RNA and cDNA synthesis from plant tissues	**2P**
2	Comparing gene expression profile in two or more treatments	**2P**
3	Cloning of gene / DNA fragment in plasmid vector and selection of recombinant clones	**4P**
4	Transformation of *Agrobacterium tumefaciens* with binary vector using freeze thaw method and selection for transformants	**3P**
5	Transformation of plant tissues using *Agrobacterium tumefaciens* based vectors.	**4P**
6	Detection of transformants using GUS/GFP/gene specific PCR	**2P**
7	Transformation of plant tissues using *Agrobacterium rhizogenes*	**4P**
8	Agroinfiltration and transient expression of gene of interest	**3P**
9	Construction of vectors for functional genomics studies	**3P**
10	Designing, evaluation and cloning of guide RNA for CRISPR-Cas based genome editing	**4P**
11	Basic linux commands for handling next generation sequencing data	**2P**
12	Next generation sequencing file formats, quality control and removal of low-quality reads	**2P**

BOT-660-MJ(H) Plant Biotechnology – II (2 Credits: 30 Lectures)		**2C**
Credit 1- Tools for understanding gene expression and molecular interactions		**15L**
1	Techniques used to study gene expression at transcription level: Northern hybridization, reverse northern hybridization, differential screening	**4L**

	and Subtractive hybridization, differential display of mRNA, ESTs, SAGE, cDNA-AFLP, DNA microarrays	
2	Studies on alterations in gene expression: Site-directed mutagenesis, Insertional mutagenesis, knock-out mutants, targeting induced local lesions in genomes (TILLING), plant genome editing using CRISPR-CAS system	**5L**
3	Gene silencing - Gene inhibition at RNA level - antisense, co-suppression, miRNAs and siRNAs. Silencing mechanisms	**2L**
4	Protein-DNA and protein-protein interactions: Chromatin immunoprecipitation assays, gel mobility shift assays, yeast 2-hybrid system, GST-pull down, BiFC, Split luciferase assay, Co-IP	**4L**
Credit 2: Advances in genome editing		**15L**
1	**CRISPR-Cas based editing**: Introduction, CRISPR and Cas types, modifications of Cas, guide RNA designing, cloning vectors and methods	**3L**
2	**CRISPR-Cas applications**: knock-out, knock-in, promoter studies, large genomic deletions, localization studies, etc.	**5L**
3	**Molecular markers:** Different types of molecular markers, Hybridization and PCR based techniques - RAPD, AFLP, SSR polymorphism, microsatellite-primed PCR, sequence-based polymorphism, single nucleotide polymorphism (SNP), Applications of molecular markers: Diversity studies, DNA fingerprinting, population structure studies, phylogenetic relationships	**4L**
4	**Biosafety concerns and regulations regarding transgenic crops**: Biosafety concerns with transgenic crops, gene containment, safer selectable markers and strategies to remove antibiotic resistance markers from transformed plants	**3L**

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2. Principles of gene manipulation. Primrose SB, Twyman RM and Old RW, 6th Edition, Blackwell Science, Oxford, 2001
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BOT-661-MJP(H) Practicals based on BOT-660-MJ(H) Plant Biotechnology – II (2 Credits: 15 Practicals)		**2C**
1	RNA isolation, purification, quantification, electrophoresis of RNA and cDNA synthesis from plant tissues	**2P**
2	Comparing gene expression profile in two or more treatments	**2P**
3	Cloning of gene / DNA fragment in plasmid vector and selection of recombinant clones	**4P**
4	PCR-based detection of polymorphism using molecular markers-RAPD/ISSR/AFLP/SSR, Construction of phylogenetic tree and analysis of polymorphism	**4P**
5	Making linkage maps from given data using map making software	**1P**
6	QTL analysis using given data	**1P**
7	Restriction and electrophoresis of plant genomic DNA and labelling of DNA fragment using DIG- DNA labelling technique	**3P**
8	Southern blotting and Southern hybridization	**3P**
9	Construction of *de novo* RNA-Seq assembly and its analysis using Trinity	**3P**
10	Genome/reference-based RNA-Seq analysis using HiSat2 tool	**3P**

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