M. Sc. (BOTANY) SYLLABUS, 2022

UNDER NATIONAL EDUCATION POLICY 2020

DEPARTMENT OF BOTANY

NORTH-EASTERN HILL UNIVERSITY

SHILLONG

Programme Objectives (POs):

M.Sc. Botany programme in Botany offers a comprehensive curriculum covering wide topics essential for understanding plant biology and its interdisciplinary applications.

- Students would be acquainted with scientific knowledge and skills to study plants in a holistic manner and trained in all areas of plant biology using a unique combination of core and discipline-specific papers with significant interdisciplinary components.
- Students would be exposed to advanced technologies that are currently in use in the study of plant life forms, their interactions with the ecosystem.
- Students would also become aware of the significance of plants and their relevance to the economy of the nation.
- Through hands-on laboratory experiments and project work, students will gain understanding into the practical aspects of Plant Biology such as ecology, taxonomy, genetics, development and biotechnology.
- With a carefully modulated blend of theoretical learning and hands-on practical exposure, graduates of the M.Sc. programme would be equipped to emerge as skilled plant biologists prepared to address the diverse challenges of plant ecology, agriculture, environmental sustainability, and biotechnological innovations.

Programme Specific Outcomes (PSOs):

PSO1. The student completing the course will be able to understand different areas of Plant Sciences such as systematics, morphology, anatomy, developmental biology, biochemistry and physiology, reproduction, plant interactions with microbes, evolution, ecology, genetics and biotechnology.

PSO2. The student completing the course will be trained in various analytical techniques of plant biology, use of plants as industrial resources for human livelihood and the use of transgenic technologies for research in plants.

PSO3. The student completing the course will be able to identify plants, design and execute experiments related to evolution, ecology, developmental biology, physiology, biochemistry, plant interactions with microbes and insects, morphology, anatomy, reproduction, genetics, microbiology, molecular biology, recombinant DNA technology, proteomics and transgenic technology. Students will be also familiarized with the use of bioinformatics tools and application of statistics to biological data.

PSO4. The student completing the course will be able to execute short research projects in any area of specializations of Plant Sciences under supervision.

FIRST SEMESTER					
Paper Code	**Name of the Paper**	**Credits (Theory)**	**Credits (Practical)**	**Total Credits**	**Total Marks**
BOT-CC-500	Microbiology, Mycology and Plant Pathology	3	1	4	100
BOT-CC-501	Algae, Bryophytes and Pteridophytes	3	1	4	100
BOT-DSEC-502	Gymnosperms and Plant Anatomy /*MOOC-1*	3	1	4	100
BOT-DSEC-503	Reproductive Biology andEmbryology/*MOOC -2*	3	1	4	100
BOT-GEC-504	Plant Resources in Human Life	4	-	4	100
Total				**20**	**500**

SECOND SEMESTER					
Paper Code	**Name of the Paper**	**Credits (Theory)**	**Credits (Practical)**	**Total Credits**	**Total Marks**
BOT-CC-505	Angiospermic Taxonomy andBiosystematics	3	1	4	100
BOT-CC-506	Plant Physiology	3	1	4	100
BOT-DSEC-507	Cell Biology and Plant Biochemistry/*MOOC-3*	3	1	4	100
BOT-DSEC-508	Bioprocess Development /*MOOC-4*	3	1	4	100
BOT-RM-509	Research Methodologies and Proposal Writing in Plant Sciences	4	-	4	100
BOT-SEC-510	Methods in Plant Sciences	3	1	4	100
Total				**24**	**600**

THIRD SEMESTER					
Paper Code	**Name of the Paper**	**Credits**		**Total Credits**	**Max. Marks**
		Theory	**Practical**		
BOT-CC-600	Genetics and Plant Breeding	3	1	4	100
BOT-CC-601	Plant Ecology and Ecosystem Analysis	3	1	4	100
BOT-CC-602	Plant Biotechnology	3	1	4	100
BOT-DSEC-603	Biodiversity and Bioprospection/ *MOOC-5*	4	-	4	100
BOT-DSEC-604	Climate Change and Plant Adaptations/ *MOOC-6*	4	-	4	100
BOT-DSEC-605	Advanced Genetic Engineering for Plant Improvement/ *MOOC-7*	4	-	4	100
	Total	**21**	**3**	**24**	**600**

FOURTH SEMESTER				
Paper Code	**Name of the**	**Credits**	**Total Credits**	**Max. Marks**
BOT-DSEC-606	**Dissertation**		20	500
	Problem identification, review of literature, proposal writing and presentation	5		
	Dissertation: Experiments, data collection, analysis, interpretation and discussion	10		
	Dissertation presentation and *Viva-Voce*	5		
	Total	**20**	**20**	**500**

EVALUATION

Paper Credit	**Marks**	**Type of Evaluation**	**Per Cent**	**Marks**	**Total Marks**
4	100	End Semester Evaluation	**75%**	75	**100**
		Sessional Evaluation	**25%**	25	

Paper code pattern for Botany**:** *BOT-Botany; BOT (CC)-Core Course requirement and compulsorily be studied in the subject.; BOT (DSEC) - Discipline-Specific Elective Course is a specialized paper within the subject; BOT (GEC) - Generic Elective Course (Multidisciplinary) to be offered to the allied/unrelated subjects; BOT (RMPW) - Research Methodologies and Proposal Writing; BOT (SEC) - Skill Enhancement Course of vocational aspect of the subject and provide hands-on training, competencies, skills etc.*

Note:

a) 1 Credit Hour is equivalent to 15 hours of teaching for theory papers and 30 hours of practical activities for Practical Papers.

b) For subjects having practical components a total of 8-12 credits may be assigned for practical excluding paper BOT (DSEC) 606.

c) MOOCs – 1-7 (Massive Open Online Courses) papers that can be opted in lieu of DSEC to a maximum of 8 credits per semester through MOOCs (SWAYAM)]

d) Sessional Evaluation Marks: The average of the best two tests/seminars/Field Work marks will be considered out of three tests/seminars/Field Work. At least, 1 test is compulsory except for paper BOT (DSEC) 606.

FIRST SEMESTER

BOT-CC-500 Microbiology, Mycology and Plant Pathology 4 Credits

Course Objectives: The course aims to increase the understanding of the students about the diversity of microorganisms, their classification, structure, growth, identification and control of plant diseases, microbiological interactions with plants and their applications.

Course Learning Outcomes: The course will help in:

1. Increasing the understanding of the students about thediversity of microorganisms, their classification, structure and growth.
2. Recognize functional ubiquity and diversity observed among different microbes.
3. Developing functional knowledge on differentiating disease caused by virus, fungi, and bacteria
4. Knowing about the various plant diseases and their control measures.
5. Interpreting the various ecological and evolutionary principles that impact microbes.
6. Developing the knowledge of the theoretical and technical skills of basic microbiology, mycology and plant pathology (sterilize, isolate, culture, preserve microbes).
7. Gaining skills necessary to isolate and handle fungi and bacteria from nature, and to discern important microscopic characteristics of fungi
8. Learning to identify and classify fungi and bacteria invisible to our naked eye by using the key characters.

Theory **3 Credits**

Unit I Microbial growth; batch culture: synchronous and continuous culture; microbial cultures: methods of isolation and maintenance of pure cultures. Various measurement of microbial growth; Effect of environmental factors on microbial growth; Microbes in extreme environments; Microbes in nanotechnology, biosensors. Microbiology of foods: Vegetables, fruits, milk, fermented and non- fermented milk products, fresh meats, poultry and non-dairy fermented foods; Microbial spoilage of food and poisoning; Food preservation: Chemical, physical and biological methods. Fermentation: batch, continuous and fed-batch. Microbes inrecovery of metal (bioleaching) and oil, Cell and enzyme immobilization, microbial enzymes of industrial interest; Novel medicines from microbes.

Unit II Criteria used in the classification of fungi with reference to vegetative and reproductive structures; parasexuality; wood decay fungi and their importance; interaction between microbes and roots of higher plants: rhizosphere
microorganisms and its significance; mycorrhizal fungi: types and applications; endophytic fungi and their importance.

Unit III Symptomology and identification of plant diseases with reference to fungi, bacteria and viruses; role of enzymes and toxins in pathogenesis; effect of temperature, pH and moisture on the development of plant diseases; mechanisms of plant pathogenicity; chemical and biological control of plant diseases; bioremediation of
contaminated soils.

Practical **1 Credit**

Unit IV
1. Collection and identification of causal organisms from diseased plant materials.
2. Isolation, identification and enumeration of bacteria and fungi from soil, litter andair.
3. Preparation and maintenance of pure cultures.
4. Gram and acid fast staining of bacterial cultures and acid fast stain.

Suggested Readings:

1. Barnett, H.L. and Hunter, B.B. (1972). Illustrated Genera of Imperfect Fungi. Burges Publishing. Co. USA.
2. Johnson, L.F. and Curl, E.A. (1972). Methods for Research on the Ecology of Soil Borne Plant Pathogens. Burgess Publishing Co. USA.
3. Domsch, K.H., Gams, W. and Anderson, T.H. (1980). Compendium of Soil Fungi. Academic Press. New Delhi, India.
4. Harley, H.L and Smith, S.E. (1983). Mycorrhizal Symbiosis. Academic Press, USA.
5. Benson, H.J. (1990). Microbiological Applications-A Laboratory Manual in General Microbiology. Wm. C. Brown Publishers. USA.
6. Mehrotra, R. S and Aneja, K.R. (1990). An Introduction to Mycology. Wiley Eastern. New Delhi, India.
7. Michael, J., Carlile, S., Watkinson, C and Gooday, G.W. (1994). The Fungi. 2nd Edition. Academic Press. USA.
8. Stevens, F.L. (1985). The Fungi Which Cause Plant Disease. IBS. New Delhi, India.
9. Blakeman, J. P. and Williamson, B. (1994). Ecology of Plant Pathogens. CAB International. UK.
10. Aneja, K.R. (1996). Experiments in Microbiology, Plant Pathology and Tissue culture. WishwaPrakashan. New Delhi, India.
11. Mishra, R. R. (1996). Soil Microbiology. CBS Publ. New Delhi, India.
12. Atlas, R.M and Bartha, R. (1997). Microbial Ecology: Fundamental Applications. 4th Edition Benjamin/Cummings Science Pub. USA.
13. Cappuccino, J.G. and Sherman, N. (1999). Microbiology- A Laboratory Manual (FourthEdition). Addison Wesley. Switzerland.
14. Dubey, R.C and Maheshwari, D.K. (1999). A Text Book of Microbiology. S. Chand &Company Ltd., New Delhi, India.
15. Tate, R.L. (2000). Soil Microbiology. 2nd Edition. John Wiley and Sons, Inc. New York, USA.
16. Sarbhoy, A.K. (2002). Text Book of Mycology, ICAR. New Delhi, India.
17. Mehrotra, R.S. and Aggarwal, A. (2003). Plant Pathology. 2nd Edition. Tata McGraw Hill, New Delhi, India.
18. Prescot, L.M., Harley, J.P and Klein, D.A. (2005). Microbiology. 6th Edition. McGraw-Hill Internationa Edition. USA
19. Madigan, M.T., Martinko, J. M and Parker, J. (2006). Brock Biology of Microorganisms. 11th Edition. Prentice Hall International, Inc., USA.
20. Webster, J. (2007). An Introduction to Fungi. Cambridge University Press, UK.
21. Webster, J and Weber, R.W.S. (2007). An Introduction to Fungi. Cambridge University Press, UK.
22. Agrios, G.N. (2008). Plant Pathology. 5th Edition. Academic Press, Reed Elsevier India Private Ltd., New Delhi, India.
23. Tortora, G.J., Funke, B.R and Case, C.L (2008). Microbiology-An Introduction. 9th Edition. Dorling Kindersley, New Delhi, India.
24. Willey, J.M., Sherwood, L.M and Woodverton, C.J. (2011). Prescott's Microbiology. 8th Edition. McGraw Hill. New Delhi, India.
25. Singh, R.P. (2012). Plant Pathology. 2nd Edition. Kalyani Publishers, New Delhi, India
26. Jeffery, C.P. (2014). Fundamental of Microbiology. 10th Edition. Jones and Bartlett Publishers, USA.
27. Singh, B. N., Hidangmayum, A., Singh, A., Shera, S. S., and Dwivedi, P. (2019). Secondary metabolites of plant growth promoting rhizomicroorganisms. Berlin, Germany: Springer.

BOT-CC-501 Algae, Bryophytes, and Pteridophytes 4 Credits

Course Objectives: The course aims to have an understanding of evolutionary diversification of early land plants, morphological and reproductive innovations in algae; bryophytes, and pteridophytes. An understanding of the process of evolution, economic values and taxonomy through study of morphology, anatomy, reproduction and developmental changes.

Course Learning Outcomes: The course will help in:

1. Understanding the taxonomic position, occurrence, thallus structure, plant morphology and reproduction of the plants
2. Knowing the vegetative and reproductive characteristics of theplants.
3. Ecological and economic importance of algae, bryophytes, pteridophytes which will help to understand their role in ecosystem functioning.
4. Understand the origin, classifications and theories of evolutions among algae, bryophytes and pteridophytes.
5. To understand the stelar evolution and seed formation habit in pteridophytes.

Theory **3 Credits**

Unit I

Algal ecology: Distribution in diverse habitats; diversity of light harvesting pigments, food reserves, economic importance, algae as biological monitor of water pollution; symbiotic algal associations; mass cultivation methods of algae; Economic importance of algae

Unit II

Origin and classification of bryophytes; vegetative and sexual reproduction; mechanism of dehiscence of capsules and dispersal of spores in bryophytes; evolution of gametophytes and sporophytes; association of bryophytes with microorganisms; anisospory and sexual dimorphism; biologically active compounds in bryophytes; ecological and economic importance of bryophytes.

Unit III

Origin of pteridophytes: theories of algal and bryophytean origins; classification; morphological, anatomical and reproductive diversity; telome theory; enation theory; stelar evolution; heterospory and seed habit; apogamy and apospory; ecological and economic importance of pteridophytes.

Practical **1 Credit**

Unit IV

1. Study of morphological features of some common freshwater, terrestrial and marine representatives of algae.
2. Study of morphology, anatomy and reproductive structures of some representatives of bryophytes and pteridophytes.

Suggested Readings:

1. Bold, H.C. and Wyne, M.J. (1978). Introduction to the Algae. Prentice Hall of India Private Ltd., New-Delhi.
2. Geissler, P and Greene, S.W. (1982). Bryophyte Taxonomy, Methods, Practices and Floristic Exploration. J Cramer, Germany.
3. Hoek, Van den, Mann, D.G. and Janes, H.M. (1995). Algae-An Introduction to Phycology, Cambridge University Press, New Delhi.
4. Parihar, N.S. (1996). The Biology and Morphology of Pteridophytes. Central Book Depot, Allahabad.
5. Stevenson, R.J., Bothwell, M.L. and Lowe, R.L. (1996). Algal Ecology-Fresh Water Benthic Ecosystems. Academic Press.
6. Kumar, H.D. (1998). Introductory Phycology. East West Press Private Ltd., New Delhi.
7. Shaw, A.J. and Goffinet, B. (2000). Bryophyte Biology. Cambridge University Press.
8. Lee, R.L. (2008). Phycology. 4th Edition. Cambridge University, New Delhi.
9. Mehlereter, K., Walker, L.A. and Sharpe, J.M. (2010). Fern Ecology. Cambridge University Press, Cambridge.
10. Barsanti, L. and Gualtieri, P. (2014). Algae- Anatomy, Biochemistry and Biotechnology- Taylor and Francis, New Delhi.
11. Bux, F, and Chisti, Y. (2016). Algae Biotechnology: Products and Processes. Springer, International Pub.Switzerland.
12. Bux, F. and Chisti, Y. (2018). Algae Biotechnology: Products and Processes. Springer, International Publishing, Cham.
13. Xia Wan Li-Bing Zhang (2022). Global new taxa of vascular plants published in 2021[J]. BiodivSci, 30(8): 22116.

BOT-DSEC-502 Gymnosperm and Plant Anatomy 4 Credits

Course Objectives: The course aims to have an understanding on distribution, morphology, anatomy, reproduction and affinities in Gymnosperms along with structural features and affinities of fossil gymnosperm and economic importance of gymnosperms. The course focuses on to have a knowledge base in understanding in shoot, leaf and wood development and current trends in plant anatomy.

Course Learning Outcomes: The students will be learning:

1. The importance of fossil and living gymnosperms.
2. To gain knowledge on the distribution of gymnosperms.
3. The development of the different organs of the plant whichwill help in their understanding of the ecosystems.
4. To understand the importance characteristics, morphology,anatomy, reproduction and affinities of living gymnosperms.
5. To explain about the affinities of fossils gymnosperms.
6. To understand the economic importance of gymnosperms.
7. To understand the Plant reproductive parts development ofmale, female gametophytes and fruits.
8. To understand vascular tissues differentiation and itsconstituents by sections and maceration, wood anatomy
9. To understand shoot, leaf development, organization, ultrastructure and the plant differentiations.
10. To gain knowledge of plant cells, tissues and their functions.

Theory **3 Credits**

Unit I Distribution of gymnosperms in India; economic importance of gymnosperms; salient structural features and affinities of fossil gymnosperms; pro-gymnosperms; Pteridospermales; Cycadeoidales (Bennettitales); Pentoxylales; Cordaitales; Diversity, morphology, anatomy, reproduction and affinities of living gymnosperms: Cycadales, Ginkgoales, Taxales, Coniferales, Ephedrales, Gnetales, and Welwitschiales.

Unit II Shoot development: Shoot apical meristem; organization, ultrastructure and histochemistry of lateral and intercalary meristems; differentiation of xylem; procambium vs. vascular cambium; factors influencing the activity of vascular cambium; wood development in relation to environmental factors; current trends and prospects in plant anatomy.

Unit III Leaf development: Leaf meristem, and histogenesis; stomatal ontogeny and classification; ultrastructure of guard cells; secretary glands and laticifers; transfer cells; fine structure of plasmalemma, microtubules and microfibrils; origin and development of primary and lateral roots; phloem: sieve tubes, sieve cells, differentiation and ultrastructure of cellular organelles; phloem protein and its function.

Practical **1 Credit**

Unit IV

1. Comparative study on the external morphology and anatomy of vegetative and reproductive parts of *Pinus, Gingko, Cedrus, Cupressus, Cryptomeria, Taxus andGnetum* etc
2. Study of the reproductive stages of genera listed above through permanentslides.
3. Use of paraffin method of microtechnique.
4. Acquaintance with ultratomy, uses of wood microtomy and other commonanatomical and histochemical methods.
3. Study of shoot and root apical meristems and lateral meristem, development of leaf and axillary bud, anomalous secondary growth, maceration and micro dissection.

Suggested Readings:

1. Sporne, K.R. (1965). The Morphology of Gymnosperms. Hutchinson & Co.
2. Trivedi, B.S and Singh, D.K. (1965). Structure and Reproduction of Gymnosperms. Shashidhar Malaviya Prakashan.
3. Cutter, E.G. (1971). Plant Anatomy: Experiment and Interpretation. Vols. 1 & 2. Edward Arnol.
4. Esau, K. (1972). Plant Anatomy. John Wiley.
5. Beck, B. (1988). Origin and Evolution of Gymnosperms. Columbia University Press.
6. Mauseth, J.D. (1988). Plant Anatomy. The Benjamin Cummings Publishers.
7. Fahn, A. (1990). Plant Anatomy. Pergmon Press.
8. Iqbal, M. (1990). The Vascular Cambium, John Wiley.
9. Shivanna, K.R. and Rangaswamy, N.S. (1992). Pollen Biology: A laboratory Manual. Springer-Verlag
10. Bhatnagar, A.K. and Moitra, A. (1996). Gymnosperms. New Age International Press.
11. Bhojwani, S.S. and Bhatnagar, S.P. (2000). The Embryology of Angiosperms, Vikas Publishing House.
12. Evert, R. F. (2006). Esau's plant anatomy: meristems, cells, and tissues of the plant body: their structure, function, and development. John Wiley & Sons.
13. Crang, R., Lyons-Sobaski, S., and Wise, R. (2018). Plant anatomy: a concept-based approach to the structure of seed plants. Springer.

BOT-DSEC-503 Reproductive Biology and Embryology 4 Credits

Course Objectives: This course aims at making the students acquainted with the fundamentals and understanding of the mechanisms associated with development and differentiation of various plant organs among the angiosperms. In order to understand this complexity, one has to look into the various aspects of growth, development and reproduction. This course is meant to answer that how the fitness attributes of plants are influenced by a variety of developmental and ecological constraints.

Course Learning Outcomes: The students will learn:

1. To gain knowledge of plant cells, tissues and their functions.
2. To identify and compare structural differences among differenttaxa of vascular plants.
3. To know the structure and development of monocot and dicotembryos.
4. To compare the function and morphology of pollen grains.
5. To describe and illustrate modern and fossil spores and pollengrains.
6. The causes and consequences of transition in the reproductiveattributes of flowering plants.
7. The different stages of concealment of ovules in angiosperms.
8. Why breakdown in self-incompatibility to self-compatibilitydoes not revert in nature.
9. What are dynamics of plant-pollinator interaction?
10. Why the development of embryo and endosperm is essentiallyinterdependent and are their exceptions to this interdependence?

Theory **3 Credits**

Unit I Development of flower (e.g. *Arabidopsis*); development of anther, ultra structure of tapetum and its role in pollen development; microsporogenesis, male sterility, male gametophyte development, heterogeneity in sperm cells; pistil and stigmatypes; megasporogenesis; polarity and ultrastructure of embryo sac.

Unit II Pollen–pistil interaction; pollen tube attraction by synergids endosperm: types, endosperm haustoria and their functions; ultrastructure and polarity of zygote, formation of tetrad, quadrant and octant proembryos; difference between monocot and dicot embryos, structure and function of suspensor; polyembryony and apomixes; parthenocarpy.

Unit III Microsporangium-Structure (T.S. of typical anther), Microsporogenesis, Structure of Pollen grain, Pollination (self and cross pollination), Development of male gametophyte, Megasporangium- Structure (L.S. of typical ovule), types of ovule. Megasporogenesis, Development of Monosporic (Polygonum type), Bisporic (Allium type) and Tetrasporic (Adoxa type) female gametophytes, Fertilization- Double fertilization and Significance, Endospermand types (Nuclear, Cellular and Helobial endosperm) , Embryo- Development of Monocot and Dicot (Crucifer type) embryo, Development of seed and Fruit (Post fertilization changes)

Practical **1 Credit**

Unit IV
1. Study of microsporogenesis and gametogenesis in anthers
2. Study of pollen viability using stains and *in vitro* pollen germination

3. Preparation of dissected whole mounts of endothecium, tapetum and ovule
4. Study of nuclear and cellular endosperm and suspensor through dissections and staining
5. Isolation of globular, heart shaped and torpedo stages of embryos from suitable seeds

Suggested Readings:

1. Maheswari, P. (1950). An Introduction to the embryology of Angiosperms. McGraw Hill Book Co.
2. Meeuse, A. D. (1966). Fundamentals of phytomorphology. Ronald Press Co.
3. Raghavan, V. (1966). Embryogenesis in angiosperms. Cambridge Univ. Press.
4. Shivanna, K .R. and Johri, B. M. (1985). The angiosperm pollen structure and function. Wiley eastern.
5. Sattler, R. (1978). Theoretical Plant morphology. Leiden University Press.
6. Swamy, B. G. L. and Krishnamurthy, K.V. (1980). From flower to fruit Tata McGraw Hill Book Co.
7. Real, L. (1983). Pollination Biology. Academic Press.
8. Johri, B. M. (1984). Embryology of angiosperms. Springer-Verlag.
9. Raghavan, V. (1986). Embryogenesis in Angiosperms. Cambridge Univ Press.
10. Endress, P. K. and Frus F. M. (1994). Early Evolution of flowers. Springer-verlag.
11. Bhojwani, S. S. and Bhatnagar, S.P. (1988). The Embryology of Angiosperms, Vikas Publishing
12. Leins, P., Tucker S.C. and Endress, P. K.(1988). Aspects of flower development. J. Cramer.
13. Shivanna, K. R. and Rangaswamy, N.S. (1992). Pollen Biology: A laboratory Manual. Springer-verlag.
14. Raghavan, V. (1999). Development Biology of flowering plants. Springer-verlag.
15. Shivanna, K. R. and Sawhney, V. K. (1997). Pollen biotechnology for crop production and improvement. Cambridge University Press.
16. Singh B. D (2015). Biotechnology: Expanding Horizons. Kalyani Publishers.

BOT-GEC-504 Plant Resources in Human Life 4 Credits

Course Objectives: This course aims to educate the students towards the advanced topics involving the plant resources for human welfare. The course also deals with medicinal plants, bioactive compounds from plants, industrial use of algae, and farming practices.

Course Learning Outcomes: The students will learn about the use of various plant resources in the daily life and the useful plants to human society. Identification feature of plant resources which include various products obtained from plants which are used for medicinal purposes, algae utilized for food, as neutraceuticals or as fuel.

Unit I Economic Botany: Uses, active principles, and value addition of the following medicinal and aromatic plants: *Aquilaria, Taxus, Mentha, Ocimum* and *Stivia.* Ethnobotany: Use of plants by the tribal societies in north-eastern India for subsistence, medicine and cultural purposes.

Unit II Algal lipids, biodiesel and biofuel production; biohydrogen and bioethanol production; genetic engineering in algae, mutagenesis for strain improvement,engineering efforts for advancement in culturing techniques; integrated multi-trophic aquaculture.

Unit III Plant resource utilization-Centres of primary diversity and secondary centres of cultivated plants; crop domestication genes; introduction to current research paradigms in major cereals, oilseeds, legumes, medicinal plants, forest trees, non-alcoholic beverages; in vitro extraction isolation of bioactive compounds from plants used as drugs in pharma industries such as antimalarials e.g. artemisinin, anticancerous, taxol, psoralen, spilanthol, connessine, antidabeticssteviosides, rebaudiosides etc.

Unit IV Interactions between farming systems and biodiversity-biodiversity in farming systems, landscape fragmentation, relationships and interdependencies of biodiversity within farming systems with outside farming systems. Case studies of farming systems of India.

Suggested Readings:

1. Jain, S.K. (1981). Glimpses of Indian ethnobotany. Oxford.
2. Frankel, O.H., Anthony, H.D. and Burdo, J.J. (1995). Conservation of Plant Biodiversity. Cambridge University Press, Cambridge. pp 299.
3. Reaka-Kulda, L.M., Wilson, D.E. and Wilson, E.O. (1997). Biodiversity II. Understanding and protecting our biological resources. Joseph Henry Press, Washington.
4. Barthlott, W. and Winiger, W. (2001). Biodiversity. Springer-Verlag, New York.
5. Brookfield, H., Padoch, C., Parsons, H., and Stocking, M. (2002). Cultivating biodiversity: understanding, analysing and using agricultural diversity. ITDG Publishing.
6. Andersen, R. A. (Ed.). (2005). Algal culturing techniques. Elsevier.
7. Rai, M., and Carpinella, M. C. (2006). Naturally occurring bioactive compounds. Elsevier.
8. Richmond, A. (Ed.). (2008). Handbook of microalgal culture: biotechnology and applied phycology. John Wiley & Sons.
9. Tow, P., Cooper, I., Partridge, I., and Birch, C. (Eds.). (2011). Rainfed farming systems. Springer Primack, R.B. (2014). Essentials of Conservation Biology. Sixth Edition. Sinauer Associates, Inc. Sunderland, Massachusetts, USA.
10. Gupta, V. K., Tuohy, M. G., O'Donovan, A., andLohani, M. (Eds.). (2015). Biotechnology of bioactive compounds: sources and applications. John Wiley & Sons.
11. Kumar, P., Tomar, R. S., Bhat, J. A., Dobriyal, M., and Rani, M. (Eds.). (2022). Agro-biodiversity and Agri-ecosystem Management. Springer Nature.
12. Sindhu, R. K., Singh, I., Shirkhedkar, A. A., andPanichayupakaranant, P. (Eds.). (2022). Herbal Drugs for the Management of Infectious Diseases. John Wiley & Sons.
13. Stubenrauch, J., Ekardt, F., Hagemann, K., and Garske, B. (2022). Forest Governance: Overcoming Trade-Offs between Land-Use Pressures, Climate and Biodiversity Protection (Volume 3). Springer Nature.
14. Suleria, H. A. R., Goyal, M. R., andAin, H. B. U. (Eds.). (2022). Bioactive Compounds from Multifarious Natural Foods for Human Health: Foods and Medicinal Plants. CRC Press.

SECOND SEMESTER

BOT-CC-505 Angiosperm Taxonomy and Biosystematics 4 Credits

Course Objectives: The course is aimed at introducing the students to the advanced concepts and principles of taxonomy, evolutionary inference of important morphological characters, important families of flowering plants, their classification and role of important characters and application of standard barcode markers in delineating species boundary.

Course Learning Outcomes: The students will be learning

1. Theories of evolution of angiosperms.
2. Systems of classification of plants.
3. Plant bar coding and the role of standard barcode markers used in delineating species.

Theory **3 Credits**

Unit I Taxonomic hierarchy; species concept and speciation; theories pertaining to the evolution of angiosperms; important Indian and world herbaria; taxonomic literature (floras, taxonomic accounts, revisionary studies); computer-aided taxonomic studies.

Unit II Systems of classification: artificial, natural and phylogenetic systems (Linnaeus, Bentham and Hooker, Engler and Prantl, Takhtajan, APG), merits and demerits of major systems of classification; biosystematics; direct and indirect methods of plant identification; practice of taxonomic key; study of selected families (Solanaceae, Brassicaceae, Cucurbitaceae, Poaceae, Liliaceae, Chenopodiaceae, Apiaceae, Orchidaceae), International Code of Botanical Nomenclature (ICN); principles of the code; ranks of taxa.

Unit III Plant Molecular Systematics: DNA sequence data, Types of sequence data, Sequence alignment, Phylogenetic analysis (parsimony, Maximum Likelihood, Bayesian approaches, Neighbor-Joining), DNA barcoding and its practicalimplications.

Practical **1 Credit**

Unit IV

1. Use of floras and manuals for identification of locally available monocot and dicot taxa up to species level.
2. Field and herbarium methods and preparation of herbarium specimens/museum specimens. (Students are required to submit at least twenty herbarium/museum specimens).
3. Familiarity with taxonomic softwares.

Suggested Readings:

1. Hutchinson, J. (1967). Key to the families of the flowering plants of the World. E. Arnold.
2. Cronquist (1968). The Evolution and Classification of Flowering Plants.
3. Heywood, V. H. (1968). Modern methods in plant taxonomy. Acad. Press.
4. Takhtajan, A. (1969). Flowering Plants Origin and Dispersal. Oliver & Boyd.
5. Jain, S.K. and Rao, R.R. (1977). A handbook of field and herbarium methods. Today & Tomorrow.
6. Sivarajan, V. V. (1990). Introduction to Principles of Plant Taxonomy. Oxford & IBH
7. Taylor, D. W. and Hickey, L. (1996). Flowering Plant Origin, Evolution and Phylogeny. Chapman & Hall. 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 Linnaean Society 181: 1-20.
8. Crawford, D. J. (2003). Plant Molecular Systematics. Cambridge University Press, Cambridge,UK.
9. Stuessy, T. F. (2009). Plant Taxonomy: The systematic Evaluation of Comparative Data. Columbia University Press, New York.
10. Soltis, P., and Doyle, J. J. (2012). Molecular Systematics of Plants II: DNA sequencing. Springer Science & Business Media.
11. Stuessy, T. F., Crawford, D. J., Soltis, D.E. and Soltis, P. S. (2014). Plant Systematics: The origin, interpretation, and ordering, of plant biodiversity. Koeltz Scientific Books, Konigstein, Germany
12. Judd, W.S., Campbell, C.S, Kellogg, E.A., Stevens, P.A. and Donoghue, M. J. (2016). Plant Systematics: A Phylogenetic Approach. SinauerAssociaes, Inc., Massachusetts.
13. Simpson, M. G. (2019). Plant Systematics. Academic press.
14. Murrell, Z. E. and Gillespie E. L. (2021). Vascular Plant Taxonomy Spiral-bound -7th edition Kendall Hunt Publishing.

BOT-CC-506 Plant Physiology **4 Credits**

Course Objectives: The course will deal with the advanced topicson plant physiology.

Course Learning Outcomes: The students will learn:

1. Water relations in plants - its movement and uptake of nutrientsby the plants.
2. The important physiological processes which lead to the growthand development of plants.
3. The importance of plant growth regulators and their mechanismof action.
4. The understanding of perception mechanism of different signals would be imparted to students.

Theory **3 Credits**

Unit I Water relations in plants: Chemical potential of water, water potential in plants, soil-plant-atmosphere continuum; movement of water in plants.
Essential nutrients; chelates; heavy-metal stress and homeostasis; molecular mechanism of mineral nutrition in plants.

Unit II Bioenergetics: laws of thermodynamics and their significance in free energy changes in biological systems; organization of the light absorbing pigment systems; mechanisms of photoexcitation of chlorophyll and electron transport chain; carbon fixations in photosyntheis; regulation of CO_2 fixation activity in plant cells; glycolysis and its regulation; fatty acid oxidation, mechanisms of oxidative decarboxylation of pyruvic acid; mitochondrial electron transport and oxidative phosphorylation; biological nitrogen fixation and assimilation of ammonia.

Unit III Plant growth regulators: auxins, gibberellins, cytokinins, abscisic acid, ethylene-physiological effects and mechanism of action; brassinosteroids- types, physiological effects and mechanism of action.
Dormancy: types and mechanism of regulation; flowering: photoperiodism and vernalization; biochemical mechanisms involved in flowering; partitioning of assimilates during different phases of plant growth.

Practical **1 Credit**

Unit IV

1. Study of the effect of organic compounds on membrane permeability.
2. Determination of water potential in plant tissues.
3. Isolation of plant pigments and determination of their absorption spectra.
4. Estimation of chlorophyll a, b and total chlorophyll content of plant tissues.
5. Measurement of Hill reaction activity by Winkler's method: effect of light wavelength and light intensity.
6. Assay of amylase induction by GA in plant tissues.
7. Assay of effect of cytokinin on chlorophyll degradation by leaf disc method.

Suggested Readings:

1. Salisbury, F.B and Ross, C. W. (1969). Plant Physiology. Wadsworth Publishing Company.
2. Noggle, G.R. and Fritz, C.J (1989). Introductory Plant Physiology. Prentice Hall.
3. Bernle, J.D. and Black, M. (1992). Seed Physiology and Biochemistry. Springer-Verlag.
4. Seigler, D.S. (1994). Plant Secondary Metabolism. Narosa.
5. Srivastava, H.S. (1994). Plant Physiology. Rastogi and Co.
6. Mattoo, A.K. and Shuttle, J.C. (1995). The Plant hormone Ethylene. CRC. Press.
7. Mukherji, S. and Ghosh, A.K. (1996). Plant Physiology. Tata- McGraw Hill.
8. Aducci, P. (1997). Signal Transduction in Plants. BirkhauserVerlag.
9. Dennis, D. (1997). Plant Metabolism. John Wiley.
10. Thomas, B. and Vince-Prue, D. (1997). Photoperiodism in plants. Academic Press.
11. Lender, D.W. (2001). Photosynthesis. Mercel Deker.
12. Lincoln, T. and Zeiger, E. (2002). Plant Physiology. Palgrave Macmillian.
13. Buchanan, B.B., Wilhelm, G. and Russel, J. (2003). Biochemistry and Molecular Biology of Plants. ASPB. US.
14. Hopkins, W.G. and Hunter N.P. (2003). Introduction to Plant Physiology. John Wiley & Sons.
15. Taiz, L., Zeiger, E., Møller, I.M. and Murphy, A. (2014). Plant Physiology and Development. Sinauer Associates.
16. Meena, M. M. (2021). Plant Physiology. Horizon Books (A Division of Ignited Minds Edutech P Ltd).
17. Hasanuzzaman, M., Nahar, K., and Brzozowski, T. (2022). Plant Stress Physiology: Perspectives in Agriculture. BoD–Books on Demand.
18. Annual Reviews of Plant Physiology and Molecular Biology. Academic Press (Annual Series)

BOT-DSEC-507 **Cell Biology and Plant Biochemistry** **4 Credits**

Course Objectives: The objective of the present course content is to provide a foundation and background in cellular entities of plants, cell structure in relation to functions, and regulatory mechanisms.

Course Learning Outcomes: The students will learn:

1. The components of endo-membrane systems and mechanisms governing intracellular trafficking in plant cells.
2. The role of plant cytoskeleton and accessory proteins in major cellular processes of plants.
3. Detailed knowledge of the enzymes and the application of immobilized enzyme technology.

Theory **3 Credits**

Unit I Plasma membrane: structure and functions; Membrane transport: ion channels and pumps; Mitochondria: structure, and organization of respiratory chain complexes; Chloroplast: organization of photosynthetic complexes; Cell cycle: phases and their regulation.

Unit II Carbohydrates and their derivatives: synthesis and inter-conversions; lipids: biosynthesis of fatty acids and their regulation; phospholipids and their role in signal transduction in cells; amino acids: structure and function, properties of amino acids; proteins: structure and function, folding and sub-unit assembly, post translational processing.

Unit III Enzymes: structure of active site, mechanisms of action, kinetics of enzymes catalysed reactions, regulation of enzyme activity; industrial enzymology: principles of immobilized enzyme technology; applications of immobilized enzymes.

Practical **1 Credit**

Unit IV

1. Estimation of starch from plant tissues by iodine reaction.
2. Estimation of sugars from plant tissues by dinitrosalycilic acid.
3. Estimation of amino acids from plant tissues by ninhydrin reaction.
4. Estimation of soluble protein content from plant tissues by Lowry's method.
5. Separation of soluble proteins by (a) gel filteration (b) gel electrophreis.
6. Assay of phosphatase activity in plant cells.

Suggested Readings:

1. Stryer, L. (1993). Biochemistry. W.H. Freeman.
2. Plumer, D. T. (1993). An Introduction to Practicals in Biochemistry. Tata McGraw Hill.
3. Conn, E.E. and Stumpf, P.K. (1994). Outlines of Biochemistry. Wiley Eastern.
4. Dey, P.M. and Harborne, J.B. (1997). Plant Biochemistry. Acad. Press.
5. Boyer, R. (1999). Concept in Biochemistry. Brooks/Cole Publ.
6. Lea, P.J. and Leagood, R.C. (1999). Plant Biochemistry and Molecular Biology. Wiley.
7. Boyer, R.F. (2012). Biochemistry Laboratory: Modern Theory and Techniques, Pearson Prentice Hall, New Jersey
8. Nelson, D.L. and Cox, M.M. (2013). Lehninger Principles of Biochemistry. 6th Edition, Freeman and Company, New York.
9. Buchanan, B.B., Gruissem, W. and Jones, R.L. (2015). Biochemistry and Molecular Biology of Plants. Wiley Blackwell, Sussex, UK.

BOT-DSEC-508 **Bioprocess Development** **4 Credits**

Course Objectives: The objective of the present course content is to provide a detailed knowledge in development of the essential skills required to utilize the living organisms for the betterment of the human beings and the nature itself.

Course Learning Outcomes: The students will learn:

1. The various processes that use complete living cells or their components (e.g., bacteria, enzymes, chloroplasts) to obtain desired products.
2. The entire process from early cell isolation and cultivation, to product development; purification of product for desiredquality.
3. Finally, the harvest of the desired density (for batch and fed-batch cultures).

Theory **3 Credits**

Unit I Raw materials for bioprocessing, comparison of chemical and biochemical processing based on energetics and environmental issues. Development of inocula, kinetics of enzymatic and microbial processes, optimisation studies, sterilization of media, air and equipment, modes of cell cultivation.
Principle of bioreactor design and their operation, types of bioreactors; microbial fermentation.

Unit II Media formulation, sterilization of equipments, gas compressor types and principles of compression, air filtration, solid and liquid handling. Industrially fermented broth (filtration and ultrafiltration), centrifugation, solvent extraction, chromatographic separation, liquid extraction of biopolymers and antibiotics ion exchange recovery of antibiotics and proteins.

Unit III Microbial biomass, single cell proteins and its nutritional values, baker's yeast, brewer's yeast, food and fodder yeast. SCP production technology bacterial protein ICI process yeast protein actinomyceatous protein, mycoproteins, algal proteins (Spirulina cultivations).
Bioconversion of waste products by microbes with special reference to biogas and organic compost; steroid bio- transformations.

Practical **1 Credit**

Unit IV

1. Isolation, identification, preparation and maintenance of pure cultures.
2. To study the growth patterns and specific growth rate of bacteria.
3. To study the effect of peptone concentration on bacterial growth
4. To study the effects of temperature on fungal and bacterial growth.
5. To study the carbohydrate fermentation tests.

Suggested Readings

1. Stanbury, P. F., Whitaker, A. and Hall, S. J. (1997). Principles of Fermentation Technology, Pergamon Press, Oxford.
2. Alexander, N.G. and Hiroshi, N. (1998). Microbial Biotechnology. W.H.Freeman& Co., USA.
3. Edward, A.B. (1992). Modern Microbiology – principles and application, WMC Brown Publishers, USA.
4. Flickinger, M.C. and Drew, S.W. (1999). Encyclopedia of bioprocess technology. Vol 1-5. John Wiley & Sons, Inc.
5. Crueger, W. and Crueger, A. (2000). Biotechnology: A textbook of industrial microbiology. Panima Publishing Corporation, India.
6. Mansi, E.M.T.E.L. and Bryle, C.F.A. (2002). Fermentation Microbiology and Biotechnology Taylor & Francis Ltd, UK.
7. Young, M.M. (2004). Comprehensive Biotechnology. The principles, applications and regulations of biotechnology in industry, agriculture and medicine, Vol 1, 2, 3 and 4 Reed Elsevier India Private Ltd, India.
8. Singh, R. P., Passos, L.P. and Magalhaes, J.R. (2005). Focus on plant molecular biology –I: nitric oxide signaling in higher plants. Studium Press, Houston, USA.
9. Tortora, G.J., Funke, B.R. and Case. C.L (2008). Microbiology– An Introduction. 9th edition.
10. Watson, J. D., Baker, T.A., Bell, S.P., Gann, A., Levine, M. and Losick, R. (2014). Molecular biology of the gene. 7th edition. Pearson.

BOT-RM-509 Research Methodologies and Proposal Writing 4 Credits

Course Objectives: The objective of the course is to provide a familiarization with research methodology and to induct the student into the overall research process and methodologies.

Course Learning Outcomes: The students will learn:

1. Collection and analyzing of the data.
2. Survey of literature for the identified problem.
3. Scientific research process and the various steps involved.
4. Research proposals, publications and ethics
5. Presentation of the results and writing of manuscripts.

Unit I Basic concepts of research: Research-definition and types of research (Descriptive *vs.* analytical; applied *vs.* fundamental; quantitative *vs.* qualitative; conceptual *vs.* empirical); Research methods *vs.* methodology; literature-reviewand its consolidation; library research; field research; laboratory research.

Unit II General laboratory practices; common calculations in botany laboratories; understanding the details on the label of reagent bottles; molarity and normality of common acids and bases; preparation of solutions; dilutions; percentage solutions; molar, molal and normal solutions; technique of handling micropipettes; common toxic laboratory chemicals and their safety measures.

Unit III Data collection and documentation of observations; maintaining a laboratory record; tabulation and generation of graphs; imaging of tissue specimens and application of scale bars; art of field photography; key biology research areas (A brief overview): Genetics, physiology, biochemistry, molecular biology, cell biology, genomics, proteomics - transcriptionalregulatory network.

Unit IV Methodology and scientific writing: Numbers, units, abbreviations and nomenclature used in scientific writing; writing references; power point presentation; poster presentation; scientific writing and ethics; introduction tocopyright-academic misconduct/plagiarism.

Suggested Readings

1. Ruzin, S.E. (1999). Plant Microtechnique and Microscopy. Oxford University Press, New York, U.S.A.
2. Stapleton, P., Yondeowei, A., Mukanyange, J. and Houten, H. (1995). Scientific Writing for Agricultural Research Scientists – a Training Reference Manual. West Africa Rice Development Association, Hong Kong.
3. Dawson, C. (2002). Practical Research Methods. UBS Publishers, New Delhi.

BOT-SEC-510 Methods in Plant Sciences 4 Credits

Course Objectives: The present course is aimed at teachingthe different techniques used in plant sciences.

Course Learning Outcomes: The students will be taught:

1. Various techniques in microbiology
2. Plant tissue culture techniques for *in vitro* culture.
3. Techniques in molecular biology.
4. Statistical methods to be used for data analysis.

Theory **3 Credits**

Unit I Techniques in Microbiology: Culture techniques of fungi and bacteria, microbe handling, preparation and maintenance of cultures; different Types of culture media; study the microbiological quality of water samples; isolation and identification of mycorrhizal associations; biofertilizers production, microbial fermentation; mushroom cultivation; molecular techniques to assess microbial community structure, function, and dynamics in the environment; culturable and unculturable bacterial analysis.

Unit II Plant Tissue Culture: Introduction to plant tissue culture, methods of sterilization; various media preparations; MS, B_5, etc.; explants selection; sterilization and inoculation; callus and cell suspension culture; micropropagation through various explants (induction of callus and somatic embryogenesis); preparation of artificial seeds; isolation of protoplasts.
Techniques in Molecular Biology: Microscopy: fluorescence, confocal, and atomic-force microscopy (AFM/SFM); spectrophotometry; Chromatography: gel filtration, adsorption, ion exchange and affinity; electrophoresis; blotting: southern, western, northern, south-western, nucleotide sequencing and analysis.

Unit III Biostatistics: Measures of variation - Standard deviation, coefficient of variation, standard error; sampling distribution; probability distributions (normal, binomial, poisson and normal); difference between non-parametric and parametric statistics; chi-square test; tests of significance: Students' 't' test, 'z' test, analysis of variance and 'F' test: one-way ANOVA; correlation and regression; introduction to statistical software.

Practical **1 Credit**

Unit IV
1. Isolation, identification and enumeration of bacteria and fungi.
2. Preparation and maintenance of pure cultures.
3. Study of different mycorrhizal associations.
4. Induction of callus and somatic embryogenesis
5. Micro propagation of plants using different explants.
6. Isolation of protoplasts

Suggested Readings

1. Alberts, B., Dennis, B., Lewis, J., Martin, R., Roberts, K., Watson, J. D. (2002). Molecular Biology of the Cell. Gerland.
2. Brown, C.M., Campbell, I. and Priest, F.G. (1990). Introduction to Biotechnology. Blackwell Scientific Publications, Oxford, London.
3. Chawla, H. S. (2000). Introduction to Plant Biotechnology. Oxford & IBH Publishing Co. Pvt. Ltd.New Delhi.
4. Dixon, R.A. and Gonzales, R. A. (Eds.) 1994. Plant Cell Culture - A Practical Approach. Oxford University Press, New York.
5. Dubey, R.C. (2015). A Textbook of Biotechnology. 5th Edition. S. Chand Publishing.
6. Gamborg, O.L and Phillips, G.C (1998). Plant Cell, Tissue Organ Culture. 1998. Narosa PublishingHouse, New Delhi.
7. Hoshmand, A.R. (1998). Statistical methods for environmental and agricultural sciences. CRCpress, New York.
8. Lodish, H. et al. (1996). Molecular cell biology. Sc. American Books.
9. Madigan, M.T., Martinko, J.M and Parker, J. (2006). Brock Biology of Microorganisms, 11th Edition. Prentice Hall International, Inc., USA.
10. Norman, G. R.,andStreiner, D. L. (2008). Biostatistics: the bare essentials. PMPH USA (BC Decker).
11. Prescot, L.M., Harley, J.P and Klein, D.A. (2005). Microbiology. 6th Edition McGraw – Hill International Edition. USA.
12. Trivedi, P.C. (Ed.) 2000. Plant Biotechnology - Recent Advances. Panima Publishing Co. NewDelhi.
13. Watson, J.D. et al. (2004). Molecular Biology of the Gene. Pearson Education.
14. Wenhao, D. (2006). PLSC 484/684-Plant Tissue Culture and Micropropagation Laboratory Manual.
15. Wulf, C and Anneliese, C. (2000). Biotechnology: A Textbook of Industrial Microbiology. Panima Publishing Corporation, New Delhi, India.

THIRD SEMESTER

BOT-CC-600 Genetics and Plant Breeding 4 Credits

Course Objectives:
This course is aimed at understanding the basic concepts of genetics, helping students to develop their analytical, quantitative and problem-solving skills from classical to molecular genetics. It will provide insight into structural and numerical aberrations, linkages and mapping of chromosomes. It will also help the students to understand the different breeding behaviour of the chromosomes for crop improvement and impart theoretical knowledge about different plant breeding objectives.

Learning Outcomes:

1. The students will learn about the eukaryotic gene and chromosome organization, mapping of eukaryotic chromosomes through linkages and recombinants both theoretically and practically by solving various related numerical problems.
2. They will learn about the fundamentals of mutation, origin and breeding behaviour at different ploidy levels, various techniques used in crop improvement
3. Students will acquaint with the fundamentals of population genetics learning phenotypic and genetic variations, understanding the mechanism of speciation through Hardy Weinberg and gene flow mechanism
4. Understand the exploitation of heterosis, male sterility for crop improvement as well as control of plant development through epigenetics
5. The students will learn and understand practically the behaviour of the chromosomes during cell divisions.

Theory **3 Credits**

Unit I Modern gene concept: eukaryotic gene organization; organization of eukaryotic chromosomes; mutations (induced and spontaneous); physical and chemical mutagens and their mode of action; molecular mechanism of mutation and recombination; Chromosomal aberrations in plants: origin, meiotic and breeding behaviours of structural aberrations; breeding behaviour of interchange heterozygotes and permanent hybrids; interchange tester sets; euploidy and aneuploidy; alien chromosome additions and substitutions; Giemsa banding of chromosomes.

Unit II Crop Genetics: introduction to crop genetics; Domestication: domestication syndrome, molecular basis of domestication, archaeological and molecular evidences of domestication (e.g. wheat, maize, cotton, tobacco, coffee, brassica spp.).
Genetic Maps and comparative genomics: Construction of linkage maps; high density maps; QTL maps; integration of genetic and physical maps; association mapping, molecular markers; High Throughput markers: SNP methods: NGS, GBS; Comparative Genomics: Gene families and their evolution.

Unit III Phenotypic variance and its components; heritability of traits and its estimation; gene frequency in a population, genetic equilibrium and Hardy-Weinberg law, barriers to gene flow and mechanism of speciation; heterosis, male sterility and its application in hybrid seed production; fluorescence *in situ* hybridization (FISH) vs. genomic *in situ* hybridization (GISH); Breeding Methods: Recombinant Inbred lines (RILS), Near Isogenic Lines (NILS), Multi Parent Populations (MPP); Epigenetics: Genomic imprinting, epigenetic control of plant development, transposable elements, RdDM, role of sRNA.

Practical **1 Credit**

Unit IV

1. Preparation of materials and study of somatic chromosomes of some common plants.
2. Karyotype preparation of somatic cells.
3. Collection of flower buds and study of meiosis and aberrant meiosis of some common plants (e.g., *Tradescantia, Datura, Phlox,* etc.).
4. Numerical exercises on linkages, crossing over and χ 2 for independence of attributes and goodness of fit.

Suggested Readings:

1. Acquaah, G. (2020). Principles of Plant Genetics and Breeding (3rd edition), WILEY Blackwell, UK
2. Allard, R. W. (1999). Principles of Plant Breeding. John Wiley and Sons.
3. Brown, T.A. (1989). Genetics- a Molecular Approach. Chapman & Hall.
4. Fukui, K. and Nakayam, S. (1996). Plant Chromosomes: Laboratory Methods. CRC Press.
5. Gardner, E. J., Simmons, M. J., Snustad, D. P. (2015). Principles of Genetics. 7th Edition. John Wiley & Sons.
6. Gupta, P.K. (1998). Genetics and Biotechnology in Crop Improvement. Rastogi & Co.
7. Hartl, D., Jones, E.W. and Lozovsky, E.R. (2006). Essential Genetics, 4th Edition, Jones and Bartlett, London.
8. Hartwell, L. H., Hood L., Goldberg, M. L., Reynolds, A. E., Silver, L. M., Veres, R. C. (2006). Genetics-From Genes to Genomes. McGraw Hill.
9. Misra, A.K. (2011). Fundamentals of Cell and Molecular Genetics. Panima Publ., New Delhi.
10. Sharma, A.K. and Sharma, A. (1999). Plant Chromosomes: Analysis, Manipulation and Engineering.Harwood Academic Publishers.
11. Sharma, J.R. (1994). Principles & Practices of Plant Breeding. Tata-McGraw Hill.
12. Singh, R.J. (2016). Plant Cytogenetics. 3rd Edition. CRC Press, London.
13. Snustad, D.P. and Simmons, M. J. (2000). Principles of Genetics. John Wiley and Sons.
14. Strickberger, M. W. (2015). Genetics. Third Edition. Phi Learning.
15. Tamarin, R.H. (2002). Principles of Genetics. Tata McGraw-Hill.
16. Varshney, R. K., Pandey M. K., Chitikineni A. (2018). Plant Genetics and Molecular Biology, Springer

BOT CC-601 Plant Ecology and Ecosystem Analysis 4 Credits

Course Objectives:
Understanding the principles of ecology and their applications in management of ecosystems and environment.

Course Learning Outcomes:

1. Develop an understanding of the principles of population, community, ecosystem and landscape ecology.
2. Develop an understanding of how the ecological principles can be applied to the management of ecosystem.

Theory **3 Credits**

Unit I Population ecology: characteristics of a population; population growth curves and models; survivorship curves, life-table analysis and age structured populations; life history strategies (r and K selection); concept of metapopulation; demes and dispersal; interdemic extinctions; types of population interactions; inter- and intra-specific competition; population regulation; symbiosis, allelopathy.

Unit II Community ecology: concept of community; Raunkiaer's Life-forms and biological spectrum; Edge effect and ecotones; Ecological niche: concept of habitat and niche, Grillenian niche, Eltonian niche, niche breadth and overlap, fundamental and realized niche, resource partitioning; Analysis of community structure: qualitative and quantitative attributes, quantitative methods of studying plant communities: importance value index; Species diversity and indices.

Unit III Ecosystem ecology: Ecosystem concept: ecosystem structure, function and services; Ecoenergetics: flow of energy, primary productivity and its measurement; primary productivity of terrestrial and aquatic ecosystems of the world; Biogeochemical cycles: carbon, nitrogen, phosphorus, and sulphur cycles; Ecosystem development: Clements' view and Gleason's view of ecological succession, models of succession; Ecosystem stability: resistance and resilience; Concept of landscape; Plant invasion hypotheses; Strategies for ecorestoration.

Practical **1 Credit**

Unit IV

1. Study of interactions between plants and environment
    a) Study of microclimatic conditions in open and closed communities
    b) Study of plastic response of plant species under contrasting environmental conditions
2. Study of physico-chemical properties of soil: (a) texture, (b) porosity, (c) water holding capacity and (d) TKN
3. Study of analytical characters of plant community using plot methods
4. Study of cohort survivorship in plant populations and life-table analysis
5. Estimation of phytomass and its distribution in different compartments in grassland communities
6. Determination of leaf-area index in the grassland community
7. Estimation of primary productivity of a terrestrial ecosystem following harvest method
8. Estimation of primary productivity of an aquatic ecosystem using light and dark bottle method.

Suggested readings

1. Andel, J.V. and Aronson, J. (2012). Restoration Ecology. Wiley-Blackwell.
2. Ambasht, R.S. and Ambasht, N.K. (2022). A Textbook of Plant Ecology. 16th Edition. CBS Publishers and Distributors, New Delhi.
3. Anderson, J.M. and Ingram, J.S.I. (1993). Tropical Soil Biology and Fertility: A Handbook of Methods. CAB International.
4. Begon, M., Townsend, C.R. and Harper, J.L. (2006). Ecology: From individuals to ecosystems. Blackwell Sciences Ltd., U.K.

5. Boucher, J. (2019). The Ecology of Plants. Callisto Reference.
6. Cain, M.L., Bowman, W. D. and Hacker, S.D. (2014). Ecology. Third Edition. Companion Website.
7. Elton, C.S. (1977). The Ecology of Invasions by Animals and Plants. Springer.
8. Ismay, M. (2016). Plant Ecology: Principles and Practices. Callisto.
9. Johnson, E.A. and Miyanishi, K. (2007). Plant Disturbance Ecology: the process and the response.
10. Jong, T. and Klinkhamer, P. (2005). Evolutionary Ecology of Plant Reproductive Strategies. Cambridge University Press.
11. Koelling, C. (2016). Functional Plant Ecology. Syrawood Publishing House.
12. Kormondy, E.J. (1996). Concepts of Ecology. Prentice Hall Inc.
13. Matthews, T.J., Triantis, K.A. and Whittaker, R.J. (2021). The Species–Area Relationship: Theory and Application. Cambridge University Press.
14. Misra, R. (1968). Ecology Workbook. Oxford & IBH.
15. Mooney, H.A. and Gordon, M. (1983). Disturbance and Ecosystems Components of Response. Springer Verlag. Berlin Heidelberg, New York, Tokyo.
16. Muller-Dombois, D. and Ellenberg, H. (1974). Aims and Methods of Vegetation Ecology. John Wiley & Sons.
17. Myers, A.A. and Giller, P. (1990). Analytical Biogeography: An Integrated Approach to the Study of Animal and Plant Distributions. Springer.
18. Newton, A.C. (2021). Ecosystem Collapse and Recovery (Ecology, Biodiversity and Conservation). Cambridge University Press.
19. Odum, E. P. and Barnett, G.W. (2005). Fundamentals of Ecology. Thomson.
20. Panda, R.M. (2022). Plant Ecology of Indian Himalaya. Springer International Publishing AG.
21. Poole, R.W. (1974). An Introduction to Quantitative Ecology. Mc Graw Hill Inc.
22. Puri, G.S. and Misra, R. (1968). Indian Manual of Plant Ecology. Scientific publishers, Jodhpur.
23. Singh, J.S., Singh, S.P. and Gupta, S.R. (2008). Ecology, Environment and Resource Conservation. Anamaya Publications, New Delhi.
24. Singh, J. S, Singh, S. P. and S. R. Gupta (2017). Ecology Environmental Science and Conservation. S Chand & Co Ltd.
25. Todaria, N.P. (2022). Plant Functions in Mountain Environment. BSMPS, Dehradun.
26. Zar, J. H. (1984). Biostatistical analysis. Prentice-Hall International.

BOT-CC-602 Plant Biotechnology 4 Credits

Course Objectives:
The main objective of the course is to equip students with a deep understanding of all the types of biotechnology processes, including both classical and modern methods. It will train students in tissue culture and transformation of plants

Course Learning Outcomes: Upon completion of this course students will be able to:

1. Distinguish plant culture techniques and culture types.
2. Role of tissue culture in plant biotechnology.
3. Evaluate several methods for improvement of crop plants using plant transformation.

Theory **3 Credits**

Unit I Tissue culture: role of *in vitro* tissue culture in plant biotechnology, anther culture, ovary culture, somatic hybridization and production of cybrids, embryo culture and rescue, clonal propagation, cryopreservation and germplasm storage, somatic embryogenesis, artificial seeds, somaclonal variations and gametoclonal variation; virus free plants; secondary metabolite production from cell cultures.

Unit II DNA modifying enzymes; Cloning vectors – Plasmids, Bacteriophage - Lambda and M13 vectors, Transgenesis: methods and applications; Direct gene transfer, Agrobacterium– mediated, electroporation, particle bombardment; screenable and selectable markers; adapters & linkers. useful gene transfers; genetic engineering of plants for insect control, herbicide resistance, resistance against viruses, quality improvement, and increased shelf-life; safety regulations for transgenic plants.

Unit III PCR-basic process, types and applications. DNA sequencing - Principle of chemical and enzymatic methods; automated DNA sequencing and high throughput sequencing; site-directed mutagenesis and protein engineering; DNA foot printing, chromosome walking.

Practical **1 Credit**

Unit IV

1. Clonal propagation of forest plants.
2. Embryo culture and rescue
3. Preparation of artificial seeds for germplasm storage
4. PCR amplication of genomic DNA from plants
5. Agro-bacterium-mediated genetic transformation of plants through co-culture.

Suggested Readings:

1. Bhojwani, S.S. and Razdan, M.K. (2004). Plant Tissue Culture: Theory and Practice, Revised Edition - (Studies in Plant Science), Elsevier Publications, Netherlands.
2. Brown, T. A. (2006). Gene Cloning and DNA Analysis-An Introduction. Blackwell University Press.
3. Chawla, H.S. (2020). Introduction to Plant Biotechnology, 3rd Edition (Pb 2020), Oxford & IBH Publishing.
4. Desmond, S.T. N. (2004). An Introduction to Genetic Engineering. Cambridge.
5. Dixon, R.A. (1995). Plant Cell Culture-A Practical Approach. IRL Press, Oxford.
6. Gamborg, O.L. and Phillips, C. (1998). Plant Cell Tissue and Organ Culture: Fundamental Methods. Narosa Publishing House, New Delhi.
7. Kirsi-Marja, Oksman-Caldentey and Wolfgang, B. (2002). Plant Biotechnology and Transgenic Plants. Marcel Dekker.
8. Malik Zainul Abdin, Usha Kiran, Kamaluddin (2017) Plant Biotechnology: Principles and Applications, Springer
9. Singh, B.D. (2015). Plant Biotechnology, Kalyani Publishers.
10. Slater, A. Scott, N. and Fowler, M.R. (2008). Plant Biotechnology: The Genetic Manipulation of Plants, Oxford.

11. Stewart, N. C. (2008). Plant Biotechnology: Principles, Techniques and Applications. John Wiley.
12. Walker, J.M. and Rapley, R. (2002). Molecular Biology and Biotechnology. Panima.
13. Watson, J. D., Baker, T.A., Bell, S.P., Gann, A., Levine, M. and Losick, R. (2014). Molecular Biology of the Gene. 7th Edition. Pearson.
14. Watson, J.D., Gilman, M., Witowski, J. and Zoller, M. (1992). Recombinant DNA. Scientific American Books.

BOT- DSEC -603 Biodiversity and Bioprospection 4 Credits

Course Objectives:
Understanding the science and current practices of Biodiversity conservation and Bioprospection.

Course Learning Outcomes: Upon completion of this course the students will be able to:
1. Understand the basic concepts of bioprospecting
2. Understand the methods of bioprospection for plants and microbes
3. Understand the basics of product development from plant and microbial bioprospection

Theory

Unit I Biodiversity: concept of biodiversity and its levels, global biodiversity, biodiversity hot spots, biodiversity of India and its *ex situ* and *in situ* conservation measures, threat to biodiversity and conservation of threatened plants; endemism; convention on biological diversity, India biodiversity act and rules; island biogeography, phytogeographic regions of India, and forest types of India.

Unit II: Bioprospection: current practices in bioprospectionon for biomolecules, genes and species; methods and instruments for isolation, identification and characterization of biomolecules: chromatographic techniques- TLC, HPLC, UPLC, HPTLC, LC-MS, GC-MS; spectroscopy-UV spectroscopy, FTIR, NMR, HRMS.

Unit III Plant bioprospectionon for drugs: preparation of extracts and standardized extracts; bioactive-guided fractionation, bio-efficacy and product development: isolation, identification and characterization of bioactive compounds, *in vitro* assays, antioxidant assay, free radical scavenging assay, cell-line assays, *in vivo* models; safety and toxicity assays; pharmacokinetics; clinical trials; regulatory framework for drug discovery.

Unit IV Microbial bioprospection for agriculture and environment: isolation, identification and characterization of microbes and microbial metabolites for agriculture and environmental uses; steps involved in product development using regulatory guidelines - biofertilizer and municipal waste degradation.

Suggested Readings:

1. Arora, R.K. and Nayar, E.R. (1984). Wild relatives of crop plants in India, NBPGR Science Monograph No.7.
2. Baker, H.G. (1978). Plants and civilization. Ill Ed. (A. Wadsworth, Belmount).
3. Barnes, R.S.K. (1998). Diversity of Living Organisms. Blackwell Sciences Ltd., U.K.
4. Bole, P.V. and Vaghani, Y. (T986). Field guide to common Indian trees, Oxford University Press, Mumbai.
5. Champion, H. G. and Seth, S. K. (1968). A Revised Survey of Forest Types of India, Govt. of India Press, New Delhi, p. 404
6. CSIR (1986). The useful plants of India. Publication and Information directorate, CSIR, New Delhi.
7. CSIR (1948 - 1976) The wealth of India, Publication and Information directorate, CSIR, New Delhi.
8. Dwivedi, A.P. (1993). Forestry in India.Surya Publications.
9. Eldredge, N. (1992). Systematics, Ecology and Biodiversity Crisis. Cambridge University Press, New York.
10. Kocchar, S.L. (1998). Economic Botany of the tropics, II Edn. MacMillan India Ltd.,

11. Lomolino, M.V., Riddle, B.R., Whittaker, R.J. and Brown, J.H. (2010). Biogeography. 4th edition. Sinauer Associates, Inc., sunderland, Massachusetts, USA.
12. Mukherjee, Pulok K. (2022). Evidence-based validation of herbal medicine: Translational research on botanicals. Elsevier.
13. Pawar, Vijaykumar, Pawar, Shubhangi , Kulkarni, Anita (2017). Overview of Analytical Methods: Spectroscopy and Chromatography
14. Saxena, Praveen K. (2001). Development of Plant-Based Medicines: Conservation, Efficacy and Safety. Springer.
15. Sharma, O.P. (1996). Economic Botany, Tata McGraw Hill co., Ltd., New Delhi,
16. Sharangi, Amit Baran and Peter, K. V. (2022). Medicinal Plants: Bioprospecting and Pharmacognosy. Taylor &Francis, New York.
17. Singh, Joginder, Sharma, Deepansh, Kumar, Gaurav, Sharma, Neeta Raj (2019). Microbial Bioprospecting for Sustainable Development. Springer.
18. Swaminathan, M.S. and Kocchar, S.L. (Es.) (1989). Plants and Society, MacMillan Publication Ltd.,
19. Thakur, R.S., Puri, H.S. and Husain, A. (1969). Major medicinal plants of India, Central Institute of medicinal and aromatic plants, Lucknow.
20. UNEP (1995). Global Biodiversity Assessment.

BOT- DSEC-604 Climate Change and Plant Adaptations 4 Credits

Course Objectives:

- To familiarize students with causes and consequences of climate change, and future scenarios of climate change.
- To acquaint the students with various adaptation and mitigation measures against climate change
- To understand plant adaptations against climate change.

Course Learning Outcomes:

1. Students would be able to understand the causes, trends, and consequences of climate change.
2. Develop an understanding of mitigation and adaptation strategies available to tackle adverse effects of climate change.
3. Understand plant adaptation strategies to climate change

Theory

Unit I Causes of Climate change: changing composition of the atmosphere due to various anthropogenic activities, greenhouse gases; trend: climate variability in the last millennium and the recent climate records, future emissions and future climate scenarios, climate models.

Unit II Assessing impacts and vulnerabilities: climate change consequences-impacts on forestry, agriculture, human health, biodiversity, soil and land, water resources; methods of vulnerability assessment; indicators of vulnerability and livelihood; climate sensitivity analysis; climate change mitigation and adaptation measures.

Unit III Plant adaptation to climate change related drought: eco-physiological mechanisms of drought tolerance in plants, molecular mechanisms of drought tolerance, screening microbes and plants/crop varieties for drought tolerance, approaches for developing drought tolerant plants/crops.

Unit IV Plant adaptation to climate change related enhanced temperature: eco-physiological mechanisms of temperature tolerance in plants, molecular mechanisms of temperature tolerance, screening microbes (metagenomics) including endophytes and plants/crop varieties for temperature tolerance (FACE), approaches for developing high temperature tolerant plants/crops.

Suggested Readings:

1. Bazzaz, F.A. (1996). Plants in changing environments. Cambridge University Press.
2. Daubenmire, R.F. (1959). Plant and Environment. 2nd Edition. John Wiley & Sons Inc.
3. Gribbin, J. 1979. Climate Change. Cambridge University Press. New York, 280p
4. Gunderson, LH, Allen CR and Holling (2012). Foundations of Ecological Resilience, Island Press.
5. John Houghton, 2009. (4th edition) Global Warming - A complete briefing. Cambridge University Press.
6. Lambers, H. and Oliveira, R.S. (2021). Plant Physiological Ecology. Springer.
7. Larcher, W. (2009). Physiological Plant Ecology: Ecophysiology and Stress Physiology of Functional Groups With contributions by numerous experts. Springer.
8. Lovejoy, Thomas E. and Hannah, Lee Jay (2006). Climate Change and Biodiversity. Yale University Press.
9. Malhotra, K.C., Barik, S. K. and Tiwari, B. K. (2009). People's perception on climate change. Astral Publications, New Delhi.
10. National Research Council (1999). Global Environmental Change: Research Pathways for the Next Decade. The National Academies Press, USA.
11. Parry, ML *et al*. (2007). Climate change: Impacts, Adaptation and Vulnerability, Cambridge University Press.
12. Patt, A *et al*. (2009). Assessing Vulnerability to global environmental change: making research useful for adaptation decision making policy, Earth scan London.
13. Rao, Prasada G.S.L.H.V., Rao, G.G.S.N. and Rao, V.U.M. (2010). Climate Change and Agriculture in India. PHI Learning Private Limited. New Delhi, India.
14. Rathinasamy, M, Chandramouli S. Phanindra K.B.V.N. Uma Mahesh (2018). Resources and Environmental Engineering II: Climate and Environment
15. Schmidt-Thome, Philip and Klein, Johannes (2013). Climate Change Adaptation in Practice. Wiley-Blackwell.
16. Shukla, P.R. Sharma, S.K. and Ramana, P.V. (2002). Climate Change and Issues, Concerns and Opportunities. Tata McGraw-Hill Publishers, New Delhi.
17. William H. Schlesinger (1997). Biogeochemistry: An Analysis of Global Change. Academic Press.

BOT- DSEC -605 Advanced Genetic Engineering for Plant Improvement 4 Credits

Course Objectives:

This course is aimed at understanding the advanced Genetic Engineering emphasizing on the plant improvement. It will provide insights into modern and advanced techniques of genome editing. It will enable the students to be at par with the recent developments in Genetic Engineering.

Learning Outcomes:

1. The students will learn the cloning and transformation techniques of the plants.
2. Students will be acquainted with the fundamentals of genome editing techniques, starting with the basic concepts till the screening of the transformants.
3. Students will be learning about the prospects of genome edited crops with regards to sustainable food security and the ethical issues

Unit I Genetic Manipulation: Introduction, Historical perspective, Cutting and joining DNA, Molecular Cloning, Constructing DNA libraries, Probes, Library screening, Expression libraries, Restriction mapping, RFLP, DNA sequencing, Transposons

Unit II Gene Expression: Introduction, Transient and stable transfection assays, *in vitro* mutagenesis, Analysis at the level of gene transcriptions: RNA expression and localization; Analysis at the level of translation: protein expression and localization; Antisense technology, Analysis of DNA-Protein, Structural analysis of proteins.

Unit III Genome editing for crop improvement: Introduction to genome engineering, basic concepts of Meganucleases, Zinc-Finger Nucleases, TALENs, CRISPR/Cas9 immune response of bacteria; Genome editing in plants using CRISPR/Cas: principle (Single guide RNA, Protospacer adjacent motives (PAM), Cas9 recruitment and cleavage of target DNA sequence), DNA repair mechanisms in plants (NHEJ and HR repair).

Unit IV Production of Plant made pharmaceuticals (PMPs): Biopharmaceuticals derived from transgenic plants; Production of recombinant Proteins, Antibodies, Vaccines and other therapeutic agents in plants; ExpressTec: High-level expression of biopharmaceuticals in cereal grains; Biopharmaceutical production in cultured plant cells; Ethical and Environmental concerns on Genetic Engineering of plants; 'Pharm' Factories of the future.

Suggested Readings:

1. Alan G. Atherly, Jack R. Girton, John F. McDonald (1998). The Science of Genetics, Published by Saunders College Pub.
2. Arencibia, A.D. (2000). Plant Genetic Engineering- Towards the Third Millennium, Publisher Elsevier Science
3. Benjamin Pierce (2017). Genetics: A Conceptual Approach (6th edn), Publishers WH Freeman
4. Daniel L. Hartl and Elizabeth W. Jones (2000) Genetics: Analysis of Genes and Genomes, Jones and Bartlett Publishers, Inc
5. Daniel L. Hartl and Bruce Cochrane (2017). Genetics: Analysis of Genes and Genomes Jones and Bartlett Publishers, Inc
6. Desmond, S.T. N. (2004). An Introduction to Genetic Engineering. Cambridge.
7. Govil C.M., Ashok Aggarwal and Jitender Sharma (2017). Plant Biotechnology and Genetic Engineering PHI Learning Pvt. Ltd.,
8. Grierson D. (2011). Plant Genetic Engineering (Plant Biotechnology Series) Publisher Springer
9. McCoy Herbert (Ed.) (2019). Plant Genetic Engineering Publisher Callisto Reference
10. Slater Adrian,Nigel Scott, and Mark Fowler (2008). Plant Biotechnology - The genetic manipulation of plants, Second Edition, Oxford University Press
11. Tzotzos G. T., Graham P. Head and Roger Hull (2009). Genetically Modified Plants - Assessing Safety and Managing Risk, Academic Press.

FOURTH SEMESTER

BOT DSEC-606-Dissertation **(20 Credits)**

Course outcomes

- To prepare the students to adapt to the research environment and understand how projects are executed in a research laboratory.
- To enable students to learn practical aspects of research and train them in the art of analysis and thesis writing.

Learning outcome

- Students should be able to learn how to select and defend a topic of their research.
- Students should learn how to effectively plan, execute, evaluate and discuss their experimental works.
- Students should be able to demonstrate considerable improvement in the following areas:
- In-depth knowledge of the chosen area of research.
- Capability to critically and systematically integrate knowledge to identify issues that must be addresses within the framework of thesis.
- Competence in research design and planning.
- Capability to create, analyze and critically evaluate different technical solutions.
- Ability to conduct research independently and to perform analytical techniques and experimental methods.
- Ability to perform project management skills, report writing, problem of solving skills and communication and interpersonal skills.

Paper Code	Name of the	Credits	Total Credits	Max. Marks
BOT DSEC– 606	**Dissertation**		20	500
	Problem identification, review of literature, proposal writing and presentation	5		
	Dissertation: Experiments, data collection, analysis, interpretation and discussion	10		
	Dissertation presentation and *Viva-Voce*	5		
	Total	**20**	**20**	**500**