PLANT PHYSIOLOGY

Course Title with Credit Load for M.Sc. in Plant Physiology

CODE	COURSE TITLE	CREDITS
PP 501*	PRINCIPLES OF PLANT PHYSIOLOGY – I: PLANT WATER RELATIONS AND MINERAL NUTRITION	2+1
PP 502*	PRINCIPLES OF PLANT PHYSIOLOGY- II: METABOLIC PROCESSES AND GROWTH REGULATION	2+1
PP 503*	PLANT DEVELOPMENTAL BIOLOGY: PHYSIOLOGICAL AND MOLECULAR BASIS	2+1
PP 504*	PHYSIOLOGICAL AND MOLECULAR RESPONSES OF PLANTS TO ABIOTIC STRESSES	2+1
PP 505*	HORMONAL REGULATION OF PLANT GROWTH AND DEVELOPMENT	2+1
PP 506	PHYSIOLOGICAL AND MOLECULAR MECHANISMS OF MINERAL NUTRIENT ACQUISITION AND THEIR FUNCTIONS	2+1
PP 507*	PHOTOSYNTHETIC PROCESSES, CROP GROWTH AND PRODUCTIVITY AND CONCEPTS OF CROP MODELLING	2+1
PP 508	PHYSIOLOGY OF FIELD CROPS	2+0
PP 509	PHYSIOLOGY OF HORTICULTURE CROPS	2+0
PP 510	SEED PHYSIOLOGY	2+1
PP 511	PHENOTYPING PHYSIOLOGICAL PROCESSES	2+0
PP 512	CROP GROWTH REGULATION AND MANAGEMENT	2+0
PP 591	MASTER’S SEMINAR	1+0
PP 599	MASTER’S RESEARCH	30

Credit: **2+1**

Course Code: **PP 501***

Title: **PRINCIPLES OF PLANT PHYSIOLOGY I**

WHY THIS COURSE?

Plant's growth and development and therefore, agricultural productivity depends on two major inputs like water and nutrients. In this regard, this course being a fundamental course will acquaint the students with the basic concepts of plant water relations and mineral nutrition. The course provides a basic knowledge on water and nutrient acquisition and their transport throughout the phenological stages. Further, it also provides hands on experience in assessing the plant and soil water status besides nutrient acquisition by plants.

AIM OF THIS COURSE

The aim of this course is to impart knowledge in the field of water relations and mineral nutrition and how plants acquire water and transport it under different soil water regimes and also make use of the water in an effective way to maximize use efficiency. In addition, the other aim is to impart knowledge of how plants minimize water loss under stress conditions besides educating the students of how plants make use of nutrients in a best possible way.

No.	Blocks	Units
1.	**Contributions of Plant Physiology to agriculture**	1. Physiology for yield improvement
		2. Physiology for quality improvement
2.	**Plant cell and anatomy**	1. Structure and physiology of cell organelles
		2. Anatomy of angiosperms and its significance
3.	**Plant water relations**	1. Soil and Plant Water Relations
		2. Water Absorption and Translocation
		3. Transpiration and Evaporative Cooling
		4. Water Productivity and Water Use Efficiency
		5. Moisture Stress and Plant Growth
4.	**Mineral nutrition**	1. Uptake, transport and translocation of assimilates and ions in plants
		2. Nutriophysiology of essential and benificial elements in plants
		3. Concepts of hydroponics and foliar nutrition
5.	**Hormonal Physiology**	1. Hormonal regulation of plant growth and development
		2. Synthetic growth regulators in agriculture

LEARNING OUTCOMES

By the end of this course, the student will be able to:

- Comprehend the fundamental concepts of plant physiological processes associated with water relation and mineral nutrition.
- Describe the physiological mechanisms of water relation and mineral nutrition.
- Recognize and describe how plants respond to mineral deficiency and toxicity.

BLOCK 1: CONTRIBUTIONS OF PLANT PHYSIOLOGY TO AGRICULTURE

Unit 1: Physiology for Yield Improvement

- Significance of Plant Physiology as a discipline
- The physiological attributes targeted for green revolution in rice and wheat, productivity increment in various crops such as maize, sugarcane, pulses, horticultural crops.

Unit 2: Physiology for Quality Improvement

- The physiological attributes targeted for quality improvement in agronomic, horticultural and tree crops.

BLOCK 2: PLANT CELL AND ANATOMY

Unit 1: Structure and Physiology of Cell Organelles

- Basic facts about cell. Definitions about cellular components.
- Structure of cell wall and plant organelles.
- Functions of cell wall and plant organelles.

Unit 2: Anatomy of Angiosperms and its Significance

- Structural organization of a plant.
- Organ, organ system, tissue systems, tissue and cellular components of plant anatomy.
- Functions of various tissues in plants

BLOCK 3: PLANT WATER RELATIONS

Unit 1: Soil and Plant Water Relations

- Water and its importance; Molecular structure of water; Properties and functions of water
- Concept of water potential; Plant cell and soil water potential and their components; Methods to determine cell and soil water potential; Concept of osmosis and diffusion
- Soil physical properties and water availability in different soils; Water holding capacity and approaches to improve WHC; Concept of FC and PWP; Water holding polymers and their relevance

Unit 2: Water Absorption and Translocation

- Root structure and functions; Root architecture and relevance in water mining; Mechanism of water absorption and translocation; Theories explaining water absorption and translocation; Aquaporins
- Mycorrhizal association and its relevance in water mining

Unit 3: Transpiration and Evaporative Cooling

- Evaporation and transpiration; relevance of transpiration; factors regulating transpiration; Measurement of transpiration; approaches to minimize evaporation and transpiration; Concept of CCATD and its relevance

- Energy balance: Solar energy input and output at crop canopy level
- Stomata- its structure, functions and distribution; Molecular mechanisms of stomatal opening and closing; Concept of guard cell turgidity; role of K and other osmolytes; role of ABA in stomatal closure; Guard cells response to environmental signals; Signaling cascade associated with stomatal opening and closure
- Antitranspirants and their relevance in agriculture

Unit 4: Water Productivity and Water Use Efficiency

- WUE and its relevance in water productivity; Transpiration efficiency, a measure of intrinsic WUE; Approaches to measure WUE; Stomatal and mesophyll regulation on WUE; Passioura's yield model emphasizing WUE

Unit 5: Moisture Stress and Plant Growth

- Physiology of water stress in plants; Effect of moisture stress at molecular, cellular, organ and plant level
- Drought indices and drought tolerance strategies
- Drought tolerance traits

BLOCK 4: MINERAL NUTRITION

Unit 1: Uptake, Transport and Translocation of Assimilates and Ions in Plants

- Mechanism of mineral uptake and translocation; Ion transporters; genes encoding for ion transporters; localization of transporters; xylem and phloem mobility; Nutrient transport to grains at maturity; Strategies to acquire and transport minerals under deficient levels.
- Role of mycorrhiza, root exudates and PGPRs in plant nutrient acquisition.

Unit 2: Nutriophysiology of Essential and Benificial Elements in Plants

- Role of mineral nutrients in plant's metabolism; Essential elements and their classification; Beneficial elements; factors influencing the nutrients availability; critical levels of nutrients.
- Functions of mineral elements in plants.
- Deficiency and toxicity symptoms in plants.

Unit 3: Concepts of hydroponics and foliar nutrition

- Foliar nutrition; significance and factors affecting total uptake of minerals; Foliar nutrient droplet size for effective entry; role of wetting agents in entry of nutrients.

BLOCK 5: HORMONAL PHYSIOLOGY

Unit 1: Hormonal Regulation of Plant Growth and Development

- Histories on the discovery of various plant hormones.
- Physiological functions of various plant hormones along with their practical applications.

Unit 2: Synthetic Growth Regulators in Agriculture

- Various synthetic forms of plant hormones.
- Applications of synthetic plant growth regulators in various crops.

PRACTICALS

1. Standard solutions and preparation of different forms of solutions

2. Studies on the basic properties of water
3. Demonstration of surface tension of water and other solvents
4. Measurement of plant water status: Relative water content and rate of water loss
5. Determination of water potential through tissue volume and Chardakov's test
6. Determination of water potential using pressure bomb, osmometer, psychrometer
7. Determination of soil moisture content and soil water potential
8. Use of soil moisture probes and soil moisture sensors
9. Measurement of transpiration rate in plants; use of porometry
10. Measurement of CTD and CCATD
11. Demonstration and use of anti-transpirants to reduce transpiration
12. Influence of potassium and ABA on stomatal opening and closing respectively
13. Deficiency and toxicity symptoms of nutrients
14. Effect of water stress on plant growth and development

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

RESOURCES BLOCK 1:

P C Trivedi 2019. Plant Physiology in Agriculture and Forestry. Aavishkar Publishers & Distributors

BLOCK 2: Crang, R., Lyons-Sobaski, S. and Wise, R., 2018. Plant anatomy: a concept-based approach to the structure of seed plants. Springer.

BLOCK 3:

Unit 1:

- Jordi Martínez-Vilalta and Núria Garcia-FornerWater potential regulation, stomatal behaviour and hydraulic transport under drought: deconstructing the iso/anisohydricconcept Plant, Cell and Environment(2017)40,962–976
- S. Mangrich, E. M. C. Cardoso, M. E. Doumer, L. P. C. Romão, M. Vidal, A. Rigol, E. H. Novotny. Improving the Water Holding Capacity of Soils of Northeast Brazil by Biochar Augmentation. Chapter 16, pp 339–354

Unit 2:

- McElrone, A. J., Choat, B., Gambetta, G. A. and Brodersen, C. R. (2013) Water Uptake and Transport in Vascular Plants. Nature Education Knowledge 4(5):6
- Hodson, R.C. and J. Acuff. 2006. Water transport in plants: anatomy and physiology. Pages 163-183, in Tested Studies for Laboratory Teaching, Volume 27 (M.A. O'Donnell, Editor). Proceedings of the 27th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 383 pages.

Unit 3:

- Caspar C.C. Chater, Robert S. Caine, Andrew J. Fleming, Julie E. Gray Plant Physiology Jun 2017, 174 (2) 624-638; DOI: 10.1104/pp.17.00183
- Petra Dietrich, Dale Sanders, Rainer Hedrich, The role of ion channels in light-dependent stomatal opening, Journal of Experimental Botany, Volume 52, Issue 363, 1 October 2001, Pages 1959–1967, https://doi.org/10.1093/jexbot/52.363.1959

Unit 4:

- Sreeman, S.M., Vijayaraghavareddy, P., Sreevathsa, R., Rajendrareddy, S., Arakesh, S., Bharti, P., Dharmappa, P., Soolanayakanahally, R., 2018. Introgression of Physiological Traits for a Comprehensive Improvement of Drought Adaptation in Crop Plants. Front. Chem. 6, 92.

Unit 5:

- SeyedYahyaSalehi-LisarHamidehBakhshayeshan-Agdam, (2016). Drought Stress in Plants: Causes, Consequences, and Tolerance. Drought Stress Tolerance in Plants, Vol 1 pp 1-16

BLOCK 4:

Unit 1:

- Pandey, Renu. (2015). Mineral Nutrition of Plants. 10.1007/978-81-322-2286-6_20.
- Barker A. V. and D. J. Pilbeam (2015). Handbook of Plant Nutrition, Second Edition. Books in Soils, Plants, and the Environment Series, the 2nd Edition, CRC Press.

Unit 2:

- Vatansever, R., Ozyigit, I. I., and Filiz, E. (2017). Essential and beneficial trace elements in plants, and their transport in roots: a review. Applied biochemistry and biotechnology, 181(1), 464-482..
- Tahat, M. M., and Sijam, K. (2012). Arbuscularmycorrhizal fungi and plant root exudates bio-communications in the rhizosphere. African Journal of Microbiology Research, 6(46), 7295-7301.

Unit 3:

- Rajasekar, M., D. UdhayaNandhini and Suganthi S. (2017) Supplementation of Mineral Nutrients through Foliar Spray – A Review. Int.J.Curr.Microbiol.App.Sci. 6(3): 2504-2513.https://doi.org/10.20546/ijcmas.2017.603.283
- Alshaal, Tarek and El-Ramady, Hassan. (2017) Foliar application: from plant nutrition to biofortification. Environment, Biodiversity and Soil Security. 10.21608/jenvbs.2017.1089.1006.

BLOCK 5:

Unit 1:

- Davies, P.J. ed., 2013. Plant hormones: Physiology, Biochemistry and Molecular Biology. Springer Science & Business Media.

General Source of Information:

- Taiz T, Zeiger E and Max Mller IM, 2018, Fundamentals of Plant Physiology
- Taiz L and Zeiger E. 2015. *Plant Physiology and development*.6th Ed
- Salisbury FB and Ross C. 1992 (4th Ed.) Plant Physiology
- Emanuel Epstein and Arnold J. Bloom.2004, Mineral nutrition of plants: principles and perspectives.2nd Ed.
- Hopkins WG and Huner NPA. 2004. *Introduction to Plant Physiology*
- Kramer, P. J., Water relations of plants
- Kirkham, M. B., Principles of soil and plant water relations
- Hopkins WG, 2008, Introduction to Plant Physiology

Credit : 2+1
Course Code : PP 502*
Title : Principles of Plant Physiology II

WHY THIS COURSE?

Mechanisms associated with growth and development determine crop performance under any given condition. Metabolic and growth processes are quite sensitive to environmental factors and hence comprehensive understanding of the physiological basis of growth and development would be essential.

AIM OF THIS COURSE

This course will impart knowledge on cellular structure and function that determine of carbon and nitrogen metabolism, lipids, enzymes and secondary metabolites in plants. Relevance of metabolic processes on growth and development leading to productivity will be dealt.

The course is organized as follows:

No.	Blocks	Units
1	**Structure and classification of biomolecules**	1. Structure and classification of carbohydrates
		2. Structure and classification of aminoacids
		3. Structure and classification of proteins
		4. Structure and classification of lipids
2	**Primary metabolism**	1. Photosynthesis: Photochemical Processes
		2. Photosynthesis: Biochemical Processes
		3. Synthesis of sugars and starch
		4. Respiration

		5. Nitrogen assimilation
		6. Protein synthesis
		7. Lipid synthesis
		8. Lipid catabolism
3	**Secondary metabolism**	1. Structure and classification of secondary metabolites
		2. Physiological roles of secondary metabolites
4	**Developmental physiology**	1. Regulation of seed germination and development
		2. Regulation of morphogenesis
		3. Regulation of reproductive phase

LEARNING OUTCOMES

By the end of this course, the student will be able to:

- Figure out the fundamental metabolic processes in plant
- Describe the physiological mechanisms and metabolic events associated with regulation of plant growth

BLOCK 1: STRUCTURE AND CLASSIFICATION OF BIOMOLECULES

Unit 1. Structure and classification of carbohydrates

- Classification, nomenclature and structure of various carbohydrates.
- Classification, nomenclature and structure of various monosaccharides.

Unit 2. Structure and classification of aminoacids

- General structure of aminoacids.
- Classification of various aminoacids.

Unit 3. Structure and classification of proteins

- Classification and structure of various proteins.

Unit 4. Structure and classification of lipids

- Classification and structure of various lipids as per LIPID MAPS database.

BLOCK 2: PRIMARY METABOLISM

Unit 1. Photosynthesis: Photochemical Processes

- Chloroplast ultrastructure with special mention of lamellar system.
- Excitation, electron and proton transfers and their relevance in energy conservation.
- Concepts of pigment systems and generation of powerful reductant and oxidant.
- Water oxidation, Water-water cycle and other aspects of electron transfer.

Unit 2. Photosynthesis: Biochemical Processes

- CO_2 diffusion mechanisms and diffusive conductances, concept of Ci determining Photosynthesis.
- RuBisCO enzyme kinetics and Calvin cycle mechanisms, Regulation of Calvin cycle and metabolite fluxes.
- Photorespiration: the advantages and inefficiencies of photosynthesis because of photorespiration.
- Concepts of CO_2 concentrating mechanisms (CCM) and spatial and temporal differences in carboxylation.
- Ecological aspects of C4 and CAM photosynthesis.
- Product synthesis, Starch and Sucrose biosynthesis.

Unit 3. Synthesis of sugars and starch

- Enzymatic synthesis and regulation of starch and sucrose synthesis.

Unit 4. Respiration

- Mitochondrial organization and functions
- Aspects of Glycolysis, TCA cycle and mitETC.
- Relevance of growth and maintenance respiration
- Concepts of CN resistance respiration – Alternate and SHAM sensitive ETC

Unit 5. Nitrogen assimilation

- Developments in d-nitrgen fixation
- Nitrate reduction and assimilation GS-GOGAT process for amino acid synthesis
- Inter-Dependence of carbon assimilation and nitrogen metabolisms

Unit 6. Protein synthesis

- Ribosomal mechanisms involved in the protein synthesis process.

Unit 7. Lipid synthesis

- Biosynthesis of fatty-acids, diacyl and triacyl glycerol, fatty acids of storage lipids.

Unit 8. Lipid catabolism

- Digestion of triacyl glycerols.
- Alpha and beta-oxidation of fatty-acids.

BLOCK 3: SECONDARY METABOLISM

Unit 1. Structure and classification of secondary metabolites

- Protective and structural metabolites.

Unit 2. Physiological roles of secondary metabolites

- Secondary metabolites and their significance in plant defense mechanisms.
- Secondary metabolites in antioxidant mechanism.

BLOCK 4: DEVELOPMENTAL PHYSIOLOGY

Unit 1. Regulation of seed germination and development

- Seed germination, dormancy and related concepts.
- Physiology of seed development

Unit 2. Regulation of morphogenesis

- Photoperiodism: Phytochromes, their structure and function
- Circadian rhythms,
- Blue light receptors: Cryptochrome and morphogenesis.
- Vernalization and its relevance in germination.

Unit 3. Regulation of reproductive phase

- Floral organ development
- Factor regulating reproduction face initiation.

PRACTICALS

1. Radiant energy measurements
2. Separation and quantification of chlorophylls
3. Separation and quantification of carotenoids
4. O2 evolution during photosynthesis
5. Anatomical identification of C3 and C4 plants
6. Measurement of gas exchange parameters, conductance, photosynthetic rate, photorespiration
7. Measurement of respiration rates
8. Estimation of reducing sugars, starch
9. Estimation of NO3, free amino acids in the xylem exudates, quantification of soluble proteins
10. Bioassays for different growth hormones- Auxins, Gibberellins, Cytokinins, ABA and ethylene
11. Demonstration of photoperiodic response of plants in terms of flowering

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

RESOURCES

Block 1:

Unit 1:

- Kirchhoff, H., (2019)Chloroplast ultrastructure in plants, New Phytologisthttps://doi.org/10.1111/nph.15730
- Jafari, T., Moharreri, E., Amin, A., Miao, R., Song, W., and Suib, S. (2016). Photocatalytic water splitting—the untamed dream: a review of recent advances. *Molecules*, *21*(7), 900.

Unit 2:

- Jensen E, Cle´ment R, Maberly SC, Gontero B. 2017 Regulation of the Calvin – Benson–Bassham cycle in the enigmatic diatoms: biochemical and evolutionary variations on an original theme. Phil. Trans. R. Soc. B 372: 20160401. http://dx.doi.org/10.1098/rstb.2016.0401
- Raven, J. A., and Beardall, J. (2015). The ins and outs of CO2. *Journal of experimental botany*, *67*(1), 1-13.
- Rae, B. D., Long, B. M., Förster, B., Nguyen, N. D., Velanis, C. N., Atkinson, N. .and McCormick, A. J. (2017). Progress and challenges of engineering a biophysical CO2- concentrating mechanism into higher plants. *Journal of Experimental Botany*, *68*(14), 3717-3737.

Unit 3:

- Hagemann, M., Weber, A. P., andEisenhut, M. (2016). Photorespiration: origins and metabolic integration in interacting compartments. *Journal of experimental botany*, *67*(10), 2915.
- Kühlbrandt, W. (2015). Structure and function of mitochondrial membrane protein complexes. *BMC biology*, *13*(1), 89.

Unit 4:

- Liesche, J., and Patrick, J. (2017). An update on phloem transport: a simple bulk flow under complex regulation. *F1000Research, 6.*
- Jensen, K. H., Berg-Sørensen, K., Bruus, H., Holbrook, N. M., Liesche, J., Schulz, A., and Bohr, T. (2016). Sap flow and sugar transport in plants. *Reviews of modern physics*, *88*(3), 035007.
- Julius, B. T., Leach, K. A., Tran, T. M., Mertz, R. A., and Braun, D. M. (2017). Sugar transporters in plants: new insights and discoveries. *Plant and Cell Physiology*, *58*(9), 1442-1460.

Unit 5:

- Rao, D. L. N. (2014). Recent advances in biological nitrogen fixation in agricultural systems. In *ProcIndianNatlSciAcad*(Vol. 80, No. 2, pp. 359-378).
- Hoffman, B. M., Lukoyanov, D., Yang, Z. Y., Dean, D. R., and Seefeldt, L. C. (2014). Mechanism of nitrogen fixation by nitrogenase: the next stage. *Chemical reviews*, *114*(8), 4041-4062.
- Mus, F., Crook, M. B., Garcia, K., Costas, A. G., Geddes, B. A., Kouri, E. D.andUdvardi, M. K. (2016). Symbiotic nitrogen fixation and the challenges to its extension to nonlegumes. *Appl. Environ. Microbiol.*, *82*(13), 3698-3710.

Unit 6:

- Pagare, S., Bhatia, M., Tripathi, N., Pagare, S., and Bansal, Y. K. (2015). Secondary metabolites of plants and their role: Overview. *Curr Trends Biotechnol Pharm*, *9*(3), 293-304.
- Jain C, Khatana S and Vijayvergia R: Bioactivity of secondary metabolites of various plants: a review. Int J Pharm Sci and Res 2019; 10(2): 494-04. doi: 10.13040/IJPSR.0975-8232.10(2).494-04..

Unit 7:

- Li, C., Li, J., Chong, K., Harter, K., Lee, Y., Leung, J.,and Schroeder, J. (2016). Toward a molecular understanding of plant hormone actions. *Molecular plant*, *9*(1), 1-3.
- Eckardt, N. A. (2015). The plant cell reviews dynamic aspects of plant hormone signaling and crosstalk.
- Jiang, K., andAsami, T. (2018). Chemical regulators of plant hormones and their applications in basic research and agriculture. *Bioscience, biotechnology, and biochemistry*, *82*(8), 1265-1300.

Unit 8:

- Zwanenburg, B., Pospíšil, T., and Zeljković, S. Ć. (2016). Strigolactones: new plant hormones in action. *Planta*, *243*(6), 1311-1326.
- Kumar, R., Khurana, A., and Sharma, A. K. (2014). Role of plant hormones and their interplay in development and ripening of fleshy fruits. *Journal of experimental botany*, *65*(16), 4561-4575.
- Gururani, M., Mohanta, T., and Bae, H. (2015). Current understanding of the interplay between phytohormones and photosynthesis under environmental stress. *International journal of molecular sciences*, *16*(8), 19055-19085.

Unit 9:

- Song, Y. H., Shim, J. S., Kinmonth-Schultz, H. A., and Imaizumi, T. (2015). Photoperiodic flowering: time measurement mechanisms in leaves. *Annual review of plant biology*, *66*, 441-464.
- Sanchez, S. E., and Kay, S. A. (2016). The plant circadian clock: from a simple timekeeper to a complex developmental manager. *Cold Spring Harbor perspectives in biology*, *8*(12), a027748.

General Text books:

- Plant Physiology, **Taiz**, Lincoln, **Zeiger**, Eduardo Origanl American edition published by Sinauer Associates, Inc., 2006; 4th ed., 2007, XXVI, ISBN: 978-3-8274-1865-4; © Springer.
- Plant Physiologyby Frank Boyer Salisbury and Cleon Ross.
- Introduction to Plant Physiology 3e (Wie)by William G. Hopkins.

Credit: **2+1**
Course Code: **PP 503***
Title: **PLANT DEVELOPMENTAL BIOLOGY: PHYSIOLOGICAL AND MOLECULAR**
BASIS

WHY THIS COURSE?

From the conventional description information on plant growth and development based on morphology and anatomy, phenomenal changes and leads taken place in the last one and half decade to address these processes at physiological, biochemical and molecular levels. This basic understanding has provided options to regulate these processes genetically using genetic and molecular tools and by interventions using chemicals and external factors. To give an example on flowering, the progress made regarding the molecular players that regulate flowering, initiation, the photoreceptors like phytochromes and their regulation by the photoperiod-short and long days has provided options to manipulate the flowering time to bring in synchrony, etc. Phenomenal progress also made in several other processes like germination, viability, root development and pollination, etc. The other major area of contribution is in tissue culture where is understanding of plant developmental biology has been put o practical use and knowledge on morphogenesis is exploited to maximum. It is very essential that the students get exposed on these aspects to complement the research programs on crop improvement.

Aim of this course

To explain about basic physiological and molecular processes concerning various facets of growth and development of plants. It provides knowledge on basic physiological processes governing developmental events in plants including senescence and fruit development and ripening. Development of vegetative tissue like shoot, leaf and root and morphogenetic phenomena like flower induction and development, factors associated with photoperiod and thermoperiod response. Regulation of morphogenesis would be studied at the molecular level providing information on genes involved. In addition, students will study how to apply the knowledge on plant development and morphogenesis using tissue culture.

The course is organized as follows:

No.	Blocks	Units
1.	**Plant Developmental Biology**	1. Evolutionary Development of Plants and Role of Environment
		2. Physiological and Molecular Determinants of Seed Biology
		3. Vegetative Growth and Organ Development
		4. Physiological and Molecular Aspects of Reproductive Growth and Development
		5. Ripening and Senescence
		6. Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature
2.	**Plant Anatomy**	1. Anatomy of roots, stem and leaf 2. Basic terminologies in anatomy and morphology of plant organs
3.	**Practical application of morphogenesis**	1. Tissue culture and micro-propagation
		2. Application of in-vitro techniques for crop improvement

LEARNING OUTCOMES

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular basis of plant growth and development. The student will develop critical insight in physiological aspects of vegetative growth and reproductive development at molecular level.

Unit 1: Evolutionary Development of Plants and Role of Environment

- Plant development and plasticity, evolution, Biodiversity
- Novel features of plant growth and development, Concept of plasticity-evolution and biodiversity, Model plants for study; Environment and development.
- Developmental stages and program; Cell-cycle, totipotency and regeneration.

Unit 2: Physiological and Molecular Determinants of Seed Biology

- Seed development- Physiology of seed development, role of hormones in embryo development; seed development and maturation.
- Seed dormancy- Physiological and molecular mechanism of seed dormancy regulation. Seed germination- seed structure and Hormonal regulation of germination, Mobilization of food reserves during seed germination.

Unit 3: Vegetative Growth and Organ Development

- Regeneration and totipotency- organ differentiation and development – role of hormones- developmental control genes in crop plants.
- Meristems in plant development.
- Shoot, Leaf, Trichome and stomate development and differentiation.
- Axillary shoot branching; Bud dormancy and growth
- Root development; Nodule development; Tuber development- hormonal control, signaling and molecular regulation- genes involved.
- Vascular bundle development- xylem and phloem differentiation

Unit 4: Physiological and Molecular Aspects of Reproductive Growth and Development

- Floral Induction and Development: Molecular and physiological mechanism of transition-vegetative to reproductive phase- floral organ initiation and development their controls.
- Development of male and female gametophyte; gametophytic mutants: pollen-stigma interaction- Pollen germination and tube growth; role of imprinting; Male sterility: and fertility restoration; Self incompatibility; Sterility and fertility restoration, Maternal gene effects, Zygotic gene effects.

- Sex determination in plants, mate choice in plants.
- Embryo and endosperm development- fertilization, role of imprinting; Parthenocarpy and apomixes

Unit 5: Ripening and Senescence

- Fruit development, enlargement, maturation and ripening; climacteric and non- climacteric fruit ripening mechanism.
- Hormonal, biochemical & Molecular aspects of fruit ripening
- Senescence and its regulation; Hormonal and environmental control of senescence; PCD in the life cycle of plants.

Unit 6: Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature

- Light control of plant development: Phytochromes and cryptochromes, phototropins, their structure, biochemical properties and cellular distribution
- Molecular mechanisms of light perception, signal transduction and gene regulation
- Photoperiodism and its significance, vernalization and hormonal control
- Circadian rhythms-biological clocks and their genetic and molecular determinants
- Thermomorphogenesis- Thermoperiodism

BLOCK 2: APPLICATION OF MORPHOGENESIS AND ITS PRACTICAL APPLICATION

Unit 7: Tissue culture and micro-propagation

- Applications of tissue culture for plant production, callus induction, somatic embryogenesis, regeneration from different explants.
- Micro-propogation, tip and axillary node culture of commercially important crops, hardening and ex-vitro establishment, concept of somatic hybridization and protoplast culture.

Unit 8: Application of in-vitro techniques for crop improvement

- Development of somoclones, identification and exploitation of somoclonal variants
- Haploid production, pollen/anther, ovule/ovary culture
- Production of secondary metabolites by tissue culture, concept of bio-fermenters.
- Plant transformation, development of transgenic plants and their characterization
- Germplasm storage, cryopreservation and regulation

PRACTICALS

1. Studying shoot apical meristem, floral meristem development and pollen tube development

2. Phenotyping photomorphogenesis: a) Studying effect of day length (short day and long day) in regulating floral induction/ flowering time in short day/long day/day neutral plants and b) effect of light on seed germination in light-sensitive and - insensitive seeds.
3. Studying effect of temperature on- a) thermomorphogenesis- measuring hypocotyl elongation under different temperature conditions and b) sex determination using cucurbits/sesame plants.
4. Measure physiological paramters of fruit ripening and study the expression of key genes regulating ripening.
5. Study the effect of ethylene, its inhbibitor and scruber on ripening (tomato).
6. Study different sterilization techniques, prepare media stocks and plant hormones.
7. Inoculate explant (seed and leaf tissue) of model plant for callus induction.
8. Subculture the callus and standardize regeneration protocol for shoot and root induction using callus and leaf explant.
9. Micro-propagation using meristem tip and axillary node culture.
10. Standerdize anther/ pollen culture for haploid production in model/crop/horticultural plant.
11. Isolation of protoplast from Arabidopsis/tobacco and its culturing
12. Study about selectable marker, reporter gene, PCR, southern and northern blotting techniques.
13. Transformation of tobacco callus or leaf explant by *Agrobacterium tumefacines* and *Agrobacterium rhizogenes* for production of transgenic
14. Molecular characterization of transgenic- PCR, southern blotting, gene expression.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

Unit 1:

- Karl J. Niklas. Plant Evolution- An Introduction to the History of Life.
- B. Bahadur *et al*. (eds.), Plant Biology and Biotechnology: Volume I: Plant Diversity, Organization, Function and Improvement
- M. De Jong and O. Leyser. Developmental Plasticity in Plants. Cold Spring Harbor Symposia on Quantitative Biology. 63-73.
- Dirk Inze and Lieven De Veylder (2006). Cell Cycle Regulation in Plant Development. Annu. Rev. Genet. 2006. 40:77–105

Unit 2

- J. Derek Bewley *et al*., Seeds-Physiology of Development, Germination and Dormancy.

- Kent J. Bradford and Hiroyuki Nonogaki (2007). Seed Development, Dormancy and Germination. Blackwell publishing.

Unit 3

- Matthew MS Evans and M. Kathryn Barton (1997). Genetics Of Angiosperm Shoot Apical Meristem Development. Annu. Rev. Plant Physiol. Plant Mol. Biol. 48:673–701.
- Keni Jiang and Lewis J. Feldman (2005). Regulation of Root Apical Meristem Development. Annu. Rev. Cell Dev. Biol. 21:485–509.
- Piazza *et al.*, (2005). Evolution of leaf developmental mechanisms. New Phytologist. 167: 693–710.
- Fiona Tooke and Nick Battey (2003). Models of shoot apical meristem function. New Phytologist. 159: 37–52.
- Zheng-Hua Ye (2002). Vascular Tissue Differentiation And Pattern Rev. Plant Biol. 55: 521-535.
- Zeevaart, J.A.D. 1976. Physiology of flower formation. Annu. Rev. Plant Physiol. 27: 321-348. Zeevaart, J.A.D. 2006. Florigen coming of age after 70 years. Plant Cell 18: 1783-1789.
- John R. Pannel. (2017). Plant Sex Determination. Current Biology 27, R191–R197.
- Mark A. Johnson *et al.*, 2019. A Fruitful Journey: Pollen Tube Navigation from Germination to Fertilization. Annu. Rev. Plant Biol. 70: 20.1–20.29
- JA Callow: Advances in Botanical Research- Incorporating Advances in Plant Pathology Vol. 44, Developmental Genetics Of The Flower.
- Thomas Jack (2004). Molecular and Genetic Mechanisms of Floral Control. The Plant Cell. 16: S1–S17.
- Anna M. Koltunow and UeliGrossniklaus (2003). APOMIXIS: A Developmental Perspective. Annu. Rev. Plant Biol. 54:547–74.
- Vernonica E. Franklin-Tong. Self-Incompatibility in Flowering Plants-Evolution, Diversity, and Mechanisms, Springer

Unit 5:

- Howard Thomas (2013). Senescence, ageing and death of the whole plant. New Phytologist. 197: 696–711.
- Eric Lam, Hiroo Fukuda and Jean Greenberg. Programmed cell death in higher plants. Reprinted from Plant Molecular Biology, Volume 44 (3), 2000
- Eng-Chong Pua and Michael R. Davey: Plant Developmental Biology - Biotechnological Perspectives.

Unit 6:

- Meng Chen (2004). Light Signal Transduction In Higher Plants Annu. Rev. Genet. 38: 87–117.

- Christian Fankhauser and Joanne Chory (1997). Light Control Of Plant Development Annu. Rev. Cell Dev. Biol. 13: 203–229.
- Mieke de Wit (2016). Light-Mediated Hormonal Regulation of Plant Growth and Development. Annu. Rev. Plant Biol. 67: 22.1–22.25
- Keara A. Franklin and Philip A. Wigge. Temperature and Plant Development. Wiley Blackwell.
- Keara A. Franklin *et al*., (2014). Interaction of light and temperature signaling. Journal of Experimental Botany. 65(11): 2859–2871.

Unit 7:

- Bhojwani SS and Razdan MK. Plant tissue culture: theory and practice, a revised edition. Elsiver publication.
- Bhojwani SS, Sant Saran, Dantu and Prem Kumar. Plant Tissue Culture: An Introductory Text.
- Edwin F George and Michael A Hall, E-book. Plant Propagation by Tissue Culture 3rd Edition.

Unit 8:

- Krishna, H., Alizadeh, M., Singh, D., Singh, U., Chauhan, N., Eftekhari, M., and Sadh, R. K. (2016). Somaclonal variations and their applications in horticultural crops improvement. 3 Biotech, 6(1), 54.
- Evans, D. A. (1989). Somaclonal variation-genetic basis and breeding applications. Trends in genetics, 5, 46-50.
- Benson, E. E., Dumet, D. J., and Harding, K. (2009). Cryopreservation of plant cells, tissues and organs. Encyclopedia of Industrial Biotechnology: Bioprocess, Bioseparation, and Cell Technology, 1-22.
- Schumacher, H. M., Westphal, M., and Heine-Dobbernack, E. (2015). Cryopreservation of plant cell lines. In Cryopreservation and Freeze-Drying Protocols (pp. 423-429). Springer, New York, NY.
- Kalaiselvi, R., Rajasekar, M., and Gomathi, S. (2017). Cryopreservation of plant materials-a review. IJCS, 5(5), 560-564.
- Jana Murovec and BorutBohanec (2012). Haploids and doubled haploids in plant breeding. Intechopen. DOI: 10.5772/29982
- Maria Antonietta Germanà (2011). Anther culture for haploid and doubled haploid production. Plant Cell, Tissue and Organ Culture. Volume 104, Issue 3, pp 283–300
- Ren, J., Wu, P., Trampe, B., Tian, X., Lübberstedt, T., and Chen, S. (2017). Novel technologies in doubled haploid line development. Plant biotechnology journal, 15(11), 1361-1370.
- Jim M. Dunwell, (2010). Haploids in flowering plants: origins and exploitataion. Plant Biotechnol J. 2010 May 1;8(4):377-424. doi: 10.1111/j.1467- 7652.2009.00498.x

- M. R. Ferrie and K. L. Caswell (2011). Isolated microspore culture techniques and recent progress for haploid and doubled haploid plant production. Plant Cell, Tissue and Organ Culture. Volume 104, Issue 3, pp 301–309
- Thijs, S., Sillen, W., Rineau, F., Weyens, N., and Vangronsveld, J. (2016). Towards an enhanced understanding of plant–microbiome interactions to improve phytoremediation: engineering the metaorganism. Frontiers in microbiology, 7, 341.

General Source Information:

- Eng-Chong Pua and Michael R. Davey: Plant Developmental Biology - Biotechnological Perspectives.
- B. Bahadur *et al*. (eds.), Plant Biology and Biotechnology: Volume I: Plant Diversity, Organization, Function and Improvement .
- J. Derek Bewley *et al*., Seeds-Physiology of Development, Germination and Dormancy.
- M. De Jongand O. Leyser. Developmental Plasticity in Plants. Cold Spring Harbor Symposia on Quantitative Biology. 63-73.
- GabyongBae and Giltsu Choi (2008). Decoding of Light Signals by Plant Phytochromes and Their Interacting Proteins. Annu. Rev. Plant Biol. 59:281–311
- Viola Willemsen and Ben Scheres (2004). Mechanisms of pattern formation in plant embryogenesis. Annu. Rev. Genet. 38:587–614
- MomokoIkeuchi, *et al*., (2016). Review- Plant regeneration: cellular origins and molecular mechanisms. Development, 143: 1442-1451.
- John R. Pannel. (2017). Plant Sex Determination. Current Biology 27, R191–R197.
- Vernonica E. Franklin-Tong. Self-Incompatibility in Flowering Plants - Evolution, Diversity, and Mechanisms. Springer.
- Peter van Dijk and Jos van Damme (2000). Apomixis technology and the paradox of sex. Trends in Plant Sciences 5(2): 81-84.

Credit	**:**	**2+1**
Course Code	**:**	**PP 504***
Title	**:**	**PHYSIOLOGICAL AND MOLECULAR RESPONSES OF PLANTS TO ABIOTIC STRESSES**

WHY THIS COURSE?

With the changing climate, plants are being more frequently exposed to abiotic stresses like, water, salinity, temperature, nutrient, radiation, etc. limiting the productivity. This will not only affect livelihoods of individual farmers but also the food security. Concerted efforts have been made to grow crops under resource limited/stressful environmental conditions and advances in physiology, molecular biology and genetics have significantly helped in this endeavor. In recent years, our understanding of the physio-morphological, biochemical and molecular adaptation of plants to resource limited/stressful environment is phenomenal. This course will outline different abiotic stresses, their impacts on agricultural productivity, stress tolerance mechanisms, stress mitigation strategies, crop improvement approaches and traits for stress tolerance.

AIM OF THIS COURSE

This course aims to describe students the abiotic-stress physiology and their effects on plant growth and productivity. This will also help students gain insights into latest developments in stress physiology and stress tolerance mechanisms, approaches for crop improvement under stressful environment.

The course is organized as follows:

No.	Blocks	Units
1.	**Abiotic Stresses**	1. Introduction to Abiotic Stresses
2.	**Drought Stress**	1. Moisture Stress Responses in Plants
		2. Stress Perception and Molecular Responses of Plants to Drought Stress
		3. Plant Adaptive Mechanisms to Drought
		4. Approaches to Improve Drought Tolerance
3.	**Salt, Heavy Metal, Water Logging, Temperature and Light Stress**	1. Salt Stress
		2. Heavy Metal Stress and Water Logging
		3. Temperature and Light Stress

LEARNING OUTCOMES

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular responses of plants to abiotic stresses. The student will develop critical insight in adaptive mechanisms of plants against various abiotic stresses.

BLOCK 1: ABIOTIC STRESSES

Unit 1: Introduction to Abiotic Stresses

- Abiotic stresses major constraints to realize potential yields of crop plants, yield losses.
- Drought prone areas in India- Frequency of occurrence of drought, Rainfed- kharif, Rabi, Areas affected by salinity, heavy metals, water logging, high temperature scenario due to global warming.

BLOCK 2: DROUGHT STRESS

Unit 1: Moisture Stress Responses in Plants

- Drought-characteristic features; water potential in the soil-plant-air continuum.
- Physiological and biochemical processes affected by drought.Oxidative

stress- generation of ROS and other cytotoxic compounds, their effect on cellular process.

- Effect on total carbon gain- decrease in photosynthetic area and function, protein turn over and lipid characters, phenology-reproductive aspects, critical stages.

Unit 2: Stress Perception and Molecular Responses of Plants to Drought Stress

- Stress perception andsignal transduction leading to expression of regulatory genes, stress specific kinases, stress specific transcription factors, functional genes associated with adaptive mechanisms

Unit 3: Plant Adaptive Mechanisms to Drought

a. Escape and desiccation avoidance mechanism

- Concept of stress escape- exploiting genetic variability in phenology, Drought avoidance mechanisms- Maintenance of cell turgor, water mining by root characters.
- Moisture conservation- Regulation of transpiration- traits reducing heat load, Stomatalfactors guard cell metabolism, moisture conservation by waxes
- Water use efficiency (WUE) and concept of water productivity- regulation of transpiration efficiency-stomatal conductance, mesophyll efficiency, relevance of WUE and Passioura's model.

b. Desiccation tolerance- Concept of acquired tolerance

- Decreased turgor mediated upregulation of cellular tolerance mechanisms, Osmolytes, managing cytotoxic compounds, ROS, RCC, scavenging - enzymatic and non-enzymatic, protein turnover, stability, chaperones, membrane stability, photo-protection of chlorophylls.

Unit 4: Approaches to Improve Drought Tolerance

- Development of genetic resources- donor genotypes for specific traits, Genomic resources- genes, QTL's regulating adaptive mechanisms, Conventional, transgenic and molecular breeding approaches to improve relevant adaptive traits, concept of trait introgression

BLOCK 3: SALT, HEAVY METAL, WATER LOGGING, TEMPERATURE AND LIGHT STRESS

Unit 1: Salt Stress

- Soil salinity-Effect of salt stress, ionic and osmotic effects; species variation in salt tolerance; glycophytes and halophytes, Salt tolerance mechanisms - exclusion, extrusion and compartmentalization, Signaling during salt stress – SOS pathway, Approaches to improve salt tolerance.

Unit 2: Heavy Metal Stress and Water Logging

- Heavy metal toxicity in plants (eg., Al, Cd), tolerance mechanisms and approaches to improve.
- Plant response to water logging, role of hormones- ethylene, mechanism

of tolerance and approaches to improve.

Unit 3:Temperature and Light Stress

- High and low temperatures; effect on plants; adaptive mechanisms, evaporation cooling, concept of cellular tolerance, protein stability, chaperones, HSPs, HSFs, membranes.
- High light and high ionizing radiation- photo oxidation and photo-inhibition; mechanisms of tolerance, plant adaptation to low light, concept of shade avoidance response (SAR)

PRACTICALS

1. Measurement of soil and plant water status.
2. Drought stress imposition and measurement of physiological and biochemical changes in plants under stress –gas exchange and fluorescence measurements.
3. Imposition of osmotic stress using PEG
4. Determination of water use efficiency as a drought resistant trait.
5. Drought Susceptibility Index (DSI) -precise field technique to identify productive genotypes under stress.
6. Approaches to quantify root characters
7. Determination of stomatal parameters and canopy temperature as a reflection of transpiration and root activity.
8. Determination of Salinity Tolerance Index.
9. Studying acclimation response - Temperature induction response.
10. Heat tolerance and membrane integrity- Sullivans heat tolerance test.
11. Quantification of osmolytes – proline under stress.
12. Oxidative stress imposition- Quantification of oxidative stress
13. Quantification of ROS under stress.
14. Estimation of ABA content in leaf and root tissues under stress.
15. Determination of Sodium and Potassium in plant tissue grown under salt stress.
16. Estimation of antioxidant enzymes.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

RESOURCES

Block 1:

Unit 1:

- Plant Physiology Book by Eduardo Zeiger and Lincoln Taiz.
- Plant physiology Book by Frank B. Salisbury, Cleon W. Ross Salisbury,

Frank B

- Pereira A (2016) Plant Abiotic Stress Challenges from the Changing Environment. Front. Plant Sci. 7:1123. doi: 10.3389/fpls.2016.01123
- Sergey Shabala, 2012. Plant Stress Physiology.
- https://www.mapsofindia.com/maps/india/drought-prone-areas.html

Block 2:

Unit 1:

- http://threeissues.sdsu.edu/three_issues_droughtfacts03.html
- Abid, M., Ali, S., Qi, L.K., Zahoor, R., Tian, Z., Jiang, D., Snider, J.L. and Dai, T., 2018. Physiological and biochemical changes during drought and recovery periods at tillering and jointing stages in wheat (Triticum aestivum L.). Scientific reports, 8(1), p.4615.
- Fathi, Amin and Barari, Davood. (2016). Effect of Drought Stress and its Mechanism in Plants. International Journal of Life Sciences. 10. 1. 10.3126/ijls.v10i1.14509.
- AshwaniPareek, Sopory. S.K, Bohnert.H.JandGovindjee 2010. Abiotic Stress Adaptation in Plants, Springer, The Netherlands
- Dumont, S. and Rivoal, J., 2019. Consequences of oxidative stress on plant glycolytic and respiratory metabolism. Frontiers in plant science, 10.
- Mittler, R., 2002. Oxidative stress, antioxidants and stress tolerance. Trends in plant science, 7(9), pp.405-410.
- Demidchik, V., 2015. Mechanisms of oxidative stress in plants: from classical chemistry to cell biology. Environmental and experimental botany, 109, pp.212-228.
- Das, K. and Roychoudhury, A., 2014. Reactive oxygen species (ROS) and response of antioxidants as ROS-scavengers during environmental stress in plants. Frontiers in Environmental Science, 2, p.53.
- Yadav, Praduman, Sunil kumar and Veena Jain. (2016). Recent Advances in Plant Stress Physiology. Daya Publishing House, New Delhi.

Unit 2:

- GyanaRanjan Rout and AnathBandhu Das. 2013. Molecular Stress physiology of plants. Springer, India.
- Combined Stresses in Plants Physiological, Molecular, and Biochemical Aspects Editors: Mahalingam, Ramamurthy (Ed.) 2015.
- Lata, Charu and Muthamilarasan, Mehanathan and Prasad, Manoj. (2015). Drought Stress Responses and Signal Transduction in Plants. In elucidation of abiotic stress signaling in plants (PP.195-225). Springer, New York,Ny. DOI: 10.1007/978-1-4939- 2540-7_7.
- Zhu, J.K., 2016. Abiotic stress signaling and responses in plants. Cell, 167(2), pp.313- 324.
- Osakabe, Y., Yamaguchi-Shinozaki, K., Shinozaki, K. and Tran, L.S.P., 2013. Sensing the environment: key roles of membrane-localized kinases in

plant perception and response to abiotic stress. Journal of experimental botany, 64(2), pp.445-458.

- Xiong, L. and Zhu, J.K., 2001. Abiotic stress signal transduction in plants: molecular and genetic perspectives. Physiologia plantarum, 112(2), pp.152-166.
- Gill, S.S., Anjum, N.A., Gill, R. and Tuteja, N., 2016. Abiotic Stress signaling in plants–an overview. Abiotic Stress Response in Plants, 3, pp.1-12.
- de Vasconcelos, M.W.P.L., Menguer, P.K., Hu, Y., Revers, L.F. and Sperotto, R.A., 2016. Stress signaling responses in plants. BioMed research international, 2016.

Unit 3:

- Khan, A., Pan, X., Najeeb, U., Tan, D.K.Y., Fahad, S., Zahoor, R. and Luo, H., 2018. Coping with drought: stress and adaptive mechanisms, and management through cultural and molecular alternatives in cotton as vital constituents for plant stress resilience and fitness. Biological research, 51(1), p.47.
- Abobatta, Waleed. (2019). Drought adaptive mechanisms of plants -a review. Adv.Agr.Environ Sci., 2(1). 42-45. DOI: 10.30881/aaeoa.00021.
- Basu, S., Ramegowda, V., Kumar, A. and Pereira, A., 2016. Plant adaptation to drought stress. F1000Research, 5.
- Gilbert, M.E. and Medina, V., 2016. Drought adaptation mechanisms should guide experimental design. Trends in plant science, 21(8), pp.639-647.
- Kamanga RM, Mbega E, Ndakidemi P (2018) Drought Tolerance Mechanisms in Plants: Physiological Responses Associated with Water Deficit Stress in *Solanum lycopersicum*. Adv Crop Sci Tech 6: 362. DOI: 10.4172/2329-8863.1000362
- Farrant, Jill and Cooper, Keren and Nell, J. (2012). Desiccation tolerance.
- Drought Stress Tolerance in Plants, Vol 1, Physiology and Biochemistry, Editors: Hossain, M.A., Wani, S.H., Bhattacharjee, S., Burritt, D.J., Tran, L.-S.P. (Eds.)
- Prakash, M. and Dr.K.Balakrishnan. 2014. Abiotic Stress tolerance in crop plants. Satish Serial Publishing House. Delhi. ISBN: 978-93-81226-92-6.
- Plant Tolerance to Individual and Concurrent Stresses Editors: Senthil-Kumar, Muthappa (Ed.) 2017.
- Fernando, V.D. and Schroeder, D.F., 2016. Role of ABA in Arabidopsis salt, drought, and desiccation tolerance. In Abiotic and Biotic Stress in Plants-Recent Advances and Future Perspectives. IntechOpen.
- Le Gall, H., Philippe, F., Domon, J.M., Gillet, F., Pelloux, J. and Rayon, C., 2015. Cell wall metabolism in response to abiotic stress. Plants, 4(1), pp.112-166.
- Hasanuzzaman, M., Nahar, K., Alam, M., Roychowdhury, R. and Fujita, M., 2013. Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants. International journal of molecular sciences, 14(5),

pp.9643-9684.

- Khan, M.I.R., Fatma, M., Per, T.S., Anjum, N.A. and Khan, N.A., 2015. Salicylic acid-induced abiotic stress tolerance and underlying mechanisms in plants. Frontiers in Plant Science, 6, p.462.

Unit 4:

- Tuberosa, Roberto and Salvi, Silvio. (2006). Genomic based approaches to improve drought tolerance in crops. Trends Plant Sci. 11. 1260-1285.
- Ali, A., Ali, Z., Quraishi, U.M., Kazi, A.G., Malik, R.N., Sher, H. and Mujeeb-Kazi, A., 2014. Integrating physiological and genetic approaches for improving drought tolerance in crops. In Emerging technologies and management of crop stress tolerance (pp. 315-345). Academic Press.
- Sahebi, M., Hanafi, M.M., Rafii, M.Y., Mahmud, T.M.M., Azizi, P., Osman, M., Abiri, R., Taheri, S., Kalhori, N., Shabanimofrad, M. and Miah, G., 2018. Improvement of drought tolerance in rice (Oryza sativa L.): Genetics, genomic tools, and the WRKY gene family. BioMed research international, 2018.
- Manavalan, L.P., Guttikonda, S.K., Phan Tran, L.S. and Nguyen, H.T., 2009. Physiological and molecular approaches to improve drought resistance in soybean. Plant and Cell Physiology, 50(7), pp.1260-1276.
- Shah, A.A., Salgotra, R.K., Wani, S.A. and Mondal, S.K., 2017. Breeding and genomics approaches to increase crop yield under drought stress in climate change scenario. European Journal of Experimental Biology, 7(4), pp.1-7.
- Dixit, S., Yadaw, R.B., Mishra, K.K. and Kumar, A., 2017. Marker-assisted breeding to develop the drought-tolerant version of Sabitri, a popular variety from Nepal. Euphytica, 213(8), p.184.
- Mir, R.R., Zaman-Allah, M., Sreenivasulu, N., Trethowan, R. and Varshney, R.K., 2012. Integrated genomics, physiology and breeding approaches for improving drought tolerance in crops. Theoretical and Applied Genetics, 125(4), pp.625-645.
- Singla-Pareek, S.L., Reddy, M.K. and Sopory, S.K., 2001. Transgenic approach towards developing abiotic stress tolerance in plants. Proceedings: Indian National Science Academy Part B, 67(5), pp.265-284.

Block 2:

Unit 1:

- Gupta, B. and Huang, B., 2014. Mechanism of salinity tolerance in plants: physiological, biochemical, and molecular characterization. International journal of genomics, 2014.
- Zhu, J.K., 2001. Plant salt tolerance. Trends in plant science, 6(2), pp.66-71.
- Moghimi, A., Yang, C., Miller, M.E., Kianian, S.F. and Marchetto, P.M., 2018. A novel approach to assess salt stress tolerance in wheat using hyperspectral imaging. Frontiers in plant science, 9.
- Isayenkov, S.V. and Maathuis, F.J., 2019. Plant Salinity Stress: Many

Unanswered Questions Remain. Frontiers in plant science, 10.

- Tuteja, N., 2007. Mechanisms of high salinity tolerance in plants. In Methods in enzymology (Vol. 428, pp. 419-438). Academic Press.
- Carillo, P., Annunziata, M.G., Pontecorvo, G., Fuggi, A. and Woodrow, P., 2011. Salinity stress and salt tolerance. In Abiotic stress in plants-mechanisms and adaptations. IntechOpen.
- Rasool, Saiema and Hameed, Asiya and Azooz, Mohamed and Rehman, Muneeb and

  O. Siddiqi, T and Ahmad, Parvaiz. (2013). Salt Stress: Causes, Types and Responses of Plants. 10.1007/978-1-4614-4747-4_1.
- Negrão, S., Schmöckel, S.M. and Tester, M., 2017. Evaluating physiological responses of plants to salinity stress. Annals of Botany, 119(1), pp.1-11.

Unit 2:

- Fukao, T., Barrera-Figueroa, B.E., Juntawong, P. and Peña-Castro, J.M., 2019. Submergence and Waterlogging Stress in Plants: A Review Highlighting Research Opportunities and Understudied Aspects. Frontiers in Plant Science, 10, p.340.
- Emamverdian, A., Ding, Y., Mokhberdoran, F. and Xie, Y., 2015. Heavy metal stress and some mechanisms of plant defense response. The Scientific World Journal, 2015.
- Mani, A. and Sankaranarayanan, K., 2018. Heavy Metal and Mineral Element- Induced Abiotic Stress in Rice Plant. In Rice Crop-Current Developments. IntechOpen.
- Barceló, Juan and Poschenrieder, Charlotte. (2008). Plant Water Relations as Affected by Heavy Metal Stress: A Review. Journal of Plant Nutrition. 13. 1-37. 10.1080/01904169009364057.
- Regulation of root traits for internal aeration and tolerance to soil water logging- flooding stress. Takaki Yamauchi, Timothy D. Colmer, Ole Pedersen, Mikio Nakazono, Plant physiology, 2018, 176(2) 1118-1130. DOI: 10.1104/pp.17.01157.

Unit 3:

- Szymańska, R., Ślesak, I., Orzechowska, A. and Kruk, J., 2017. Physiological and biochemical responses to high light and temperature stress in plants. Environmental and Experimental Botany, 139, pp.165-177.
- Maduraimuthu, Djanaguiraman and Prasad, P. V. Vara. (2014). High temperature stress..
- Nahar, K., Hasanuzzaman, M., Ahamed, K.U., Hakeem, K.R., Ozturk, M. and Fujita, M., 2015. Plant responses and tolerance to high temperature stress: role of exogenous phytoprotectants. In Crop production and global environmental issues (pp. 385-435). Springer, Cham.
- Mathur, S., Agrawal, D. and Jajoo, A., 2014. Photosynthesis: response to high temperature stress. Journal of Photochemistry and Photobiology B: Biology, 137, pp.116-126.

- Ort, D.R., 2001. When there is too much light. Plant physiology, 125(1), pp.29-32.
- Demmig-Adams, B. and Adams Iii, W.W., 1992. Photoprotection and other responses of plants to high light stress. Annual review of plant biology, 43(1), pp.599-626.
- Dietz, K.J., 2015. Efficient high light acclimation involves rapid processes at multiple mechanistic levels. Journal of Experimental Botany, 66(9), pp.2401-2414.

Credit : **2+1**

Course Code : **PP 505***

Title : **HORMONAL REGULATION OF PLANT GROWTH AND DEVELOPMENT**

WHY THIS COURSE?

Many plant growth and developmental processes are regulated by phytohormones. It is important to understand the hormone biosynthesis, structure, function, signal transduction and their practical application. It is also important to provide basic knowledge on manipulating growth and developmental processes using plant hormones.

AIM OF THIS COURSE

It provides knowledge on the fundamentals of hormone biosynthesis, homeostasis, transport and signaling and the role in regulating basic physiological processes governing developmental events in plants.The role of classical hormones on developmental processes from germination, shoot and root apical meristem differentiation, flowering, seed maturation and senescence. The aim of this course is to appraise the students about structure and function of plant growth regulators.

The course is organized as follows:

No.	Blocks	Units
1.	**Plant Growth and Development : Hormonal Regulation**	1. Introduction to Plant Hormones
		2. Plant Hormones - Discovery and Metabolism
		3. Physiological Role of Hormones in Plant Growth and Development
		4. Endogenous Growth Substances other than Hormones
		5. Hormone Signaling
		6. Key Genes Regulating Hormone Levels and Functions
		7. Crosstalk of Hormones in Regulation of Plant Growth and Development Processes

		8. Practical Utility of Growth Regulators in Agriculture and Horticulture

LEARNING OUTCOMES

After successful completion of this course, the students are expected to be able to:

1. Acquire basic knowledge about plant hormones and plant growth regulators.
2. Understand the physiological roles and mechanisms of actions of plant hormone.
3. Obtain practical knowledge about application of plant growth regulators in agricultural and horticulture.

BLOCK 1: PLANT GROWTH AND DEVELOPMENT: HORMONAL REGULATION

Unit 1: Introduction to Plant Hormones

- Growth, differentiation and development regulated by plant growth substances
- Definition and classification of growth regulating substances:Classical hormones
- Definition and classification of growth regulating substances:Endogenous growth substances other than hormones, Synthetic chemicals

Unit 2: Plant Hormones - Discovery and Metabolism

- Discovery, biosynthetic pathways and metabolism of Auxin
- Discovery, biosynthetic pathways and metabolism of Gibberellins
- Discovery, biosynthetic pathways and metabolism of Cytokinins
- Discovery, biosynthetic pathways and metabolism of Abscisic acid
- Discovery, biosynthetic pathways and metabolism of Ethylene
- Discovery, biosynthetic pathways and metabolism of Brassinosteroids
- Discovery, biosynthetic pathways and metabolism of Strigolactones

Unit 3: Physiological Role of Hormones in Plant Growth and Development

- Physiological functions of Auxin and use of mutants and transgenic plants in elucidating the physiological functions
- Physiological functions of Gibberellins and use of mutants and transgenic plants in elucidating the physiological functions
- Physiological functions of Cytokinins and use of mutants and transgenic plants in elucidating the physiological functions
- Physiological functions of Abscisic acid and use of mutants and transgenic plants in elucidating the physiological functions
- Physiological functions of Ethylene and use of mutants and transgenic plants in elucidating the physiological functions
- Physiological functions of Brassinosteroids and Strigolactones and use of mutants and transgenic plants in elucidating the physiological functions

- Discovery, biosynthetic pathways metabolism and physiological roles of Salicylic acid and Peptide hormones

Unit 4: Endogenous Growth Substances other than Hormones

- Discovery, biosynthetic pathways metabolism and physiological role of Polyamines and Karrikins
- Discovery, biosynthetic pathways metabolism and physiological roles of Jasmonates and Tricontanol
- Discovery, biosynthetic pathways metabolism and physiological roles of systemins Concept of death hormone
- Recent developments in elucidating responses of Salicylic acid, Peptide hormones and Polyamines at physiological and molecular level
- Recent developments in elucidating responses of Jasmonates, Systemins, Karrikins and Tricontanol at physiological and molecular level

Unit 5: Hormone Signaling

- Hormone signal perception, transduction - Receptors, components and mechanism (Auxin, Gibberellin, Cytokinin, ABA and Salicylic acid)
- Hormone signal perception, transduction - Receptors, components and mechanism (Ethylene, Jasmonate, Brassinosteroids and strigolactones)
- Advances in elucidating the structure and function of receptors and signaling components of important hormones

Unit 6: Key Genes Regulating Hormone Levels and Functions

- Genomics approaches to regulate hormone metabolism and its effect on plant growth and development – case studies

Unit 7: Crosstalk of Hormones in Regulation of Plant Growth and Development Processes

- Crosstalk of Hormones in Regulation of Plant Growth and Development Processes: Floral transition, reproductive development, Shoot and root apical meristem development

Unit 8: Practical Utility of Growth Regulators in Agriculture and Horticulture

- Practical Utility of Growth Regulators in Agriculture and Horticulture: Rooting of cuttings, Vine and brewing industry, Promotion of gynoecious flowers, hybrid rice production, induction of flowering in pine apple, cucurbits.
- Practical Utility of Growth Regulators in Agriculture and Horticulture: Delaying of senescence and ripening, Production of dwarf plants for ornamental purpose, As herbicides, Reduction in flower and fruit drop

PRACTICALS

1. Extraction of Auxins from plant tissue
2. Separation and detection of Auxins by GC / GC-MS / HPLC / Immunological technique
3. Bioassay of auxin- effect on rooting of cuttings

4. Extraction of abscisic acid (ABA) from plant tissue
5. Separation and detection of ABA by HPLC/Immunological technique
6. ABA bioassays- effect on stomatal movement
7. Preparation of samples for ethylene estimation in plant tissue
8. Estimation of ethylene in plant tissues using gas chromatography
9. Ethylene bioassays, estimation using physico-chemical techniques- effect on breaking dormancy in sunflower and groundnut
10. Extraction of Gibberellins from plant tissue- GC / GC-MS / HPLC
11. Separation and detection of GA by GC / GC-MS / HPLC/Immunological technique
12. GA bioassays- effect on germination of dormant seeds
13. Cytokinin- extraction from plant tissue
14. Separation and detection of cytokinin by GC / GC-MS / HPLC
15. Cytokinin bioassays- effect on apical dominance and senescence/ stay green

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

RESOURCES

- Davies, P.J. 2004, Plant Hormones: Biosynthesis, Signal Transduction and Action, 2nd Edition. Kluwer Academic Publishers, Dordrecht, The Netherlands.
- Hedden, P. and Thomas, S.J. 2006. Plant Hormone Signalling, Blackwell Publishing Ltd., Oxford, UK.
- Osborne, D.J. and McManus, M.T. 2005. Hormones, Signals and Target Cells in Plant Development. Cambridge University Press, New York, USA.
- Tucker, G.A. and Roberts, J.A. 2000. Plant Hormone Protocols. Humana Press-Springer Science, New York, USA.
- Buchanan B B, Gruissem W and Jones R L Biochemistry and Molecular biology of Plants, 2nd Edition
- Lincoln Taiz and Eduardo Zeiger. Plant Physiology and Development, 6th Edition.
- Teaching Tools in Plant Biology, The American Society of Plant Biologists
- The Arabidopsis Book(http://www.arabidopsisbook.org/)

Credit : **2+1**
Course Code : **PP 506**
Title : PHYSIOLOGICAL AND MOLECU MECHANISMS OF MINERAL NUTRIENT ACQUISITION AND THEIR FUNCTIONS

WHY THIS COURSE?

In both basic and applied plant sciences, an understanding of the mineral nutrition of plants is of fundamental importance. Nutrient element forms the skeleton of any organic molecule in the organism vis-à-vis plant. Apart from the conventional information on criteria of essentiality, nutrient uptake pathways, function of essential elements and their deficiency and toxicity symptoms, remarkable advances have been made at physiological and molecular level. Exploration of the physiological mechanisms adopted by plants to tolerate the deficiency of specific nutrient element provides an opportunity alter the plants' ability to cope with the low nutrient condition. Identification and functional validation of various transporters involved in nutrient uptake and distribution, deciphering the sensing and signaling of nutrient starvation response and their regulatory network provides options to develop nutrient uptake and utilization efficient crops. In the era of Omics, 'ionomics' provides the total elemental composition of the plant and is a powerful approach to the functional analysis of its genes and the gene networks. Besides, it is also essential to expose the students to various conventional and high-throughput phenotyping techniques to identify the nutrient efficient 'donors', traits and QTLs/candidate genes to complement the research program on crop improvement.

AIM OF THIS COURSE

It provides knowledge on basic physiological processes governing nutrient uptake, physiological role of elements, factors influencing uptake, internal remobilization of nutrient element during starvation and adaptation strategies. Regulation of nutrient uptake and translocation would be studied at the molecular level providing information on genes and other signaling factors involved. The aim of this course is to make the students understand the physiological and molecular basis of nutrient uptake, translocation and utilization and to apply this knowledge in genetic improvement of crop plants.

The course is organized as follows:

No.	Blocks	Units
1.	**Mineral Nutrient: Classification, Function, Availability, Deficiency and Toxicity**	1. Mineral Elements : Classification, Function, Deficiency and Toxicity
		2. Nutrient Availability at Rhizosphere
2.	**Nutrient Uptake, Translocation and Acquisition**	1. Ion Uptake Mechanisms
		2. Ion Transport to Shoot and Grains
		3. Physiological and Molecular Mechanism of Nutrient Acquisition and Transport : Macronutrients
		4. Physiological and Molecular Mechanism of Nutrient Acquisition and Transport : Micro and Beneficial Nutrients

		5. Microbes, Fungal Association for Nutrient Acquisition
		6. Nutrient Delivery
3.	**Nutrient Efficiency of Crop**	1. Improving Nutrient Acquisition and Efficiency of Crops

LEARNING OUTCOMES

By the end of this course, the student will be able to:

- comprehend the fundamental concepts of mineral nutrition of plant.
- describe the physiological and molecular mechanisms of acquisition and translocation of nutrient.
- describe the basis of differential nutrient efficiency.

BLOCK 1: MINERAL NUTRIENT: CLASSIFICATION, FUNCTION, AVAILABILITY, DEFICIENCY ANDTOXICITY

Unit 1: Mineral Elements: Classification, Function, Deficiency and Toxicity

- Classification based on mobility and characteristic features; physiological role in regulating plant growth, metabolism, development and human health- Regulatory Dietary Allowance (RDA)
- Deficiency and toxicity of macro, micro and beneficial elements
- Tolerance of plants to nutrient toxicity, hyper-accumulators of nutrients: Concept of phytoremediation

Unit 2: Nutrient Availability at Rhizosphere

- Biological and chemical reactions influencing nutrient availability near the root system, interaction between ions in the rhizosphere
- Rhizosphere chemistry in relation to plant nutrition- chemical reactions, root exudates to mobilize nutrients

BLOCK 2: NUTRIENT UPTAKE, TRANSLOCATION AND ACQUISITION

Unit 1: Ion Uptake Mechanisms

- Mineral salt absorption- chemical potential of solute- Nernst equation- passive uptake- diffusion, ion exchange-Donnan Equilibrium, mass flow of ions
- Mediated transport- Facilitated diffusion -ionophores; membrane transport proteins- active transport-ion channels, Primary and secondary transport- carriers and pumps

Unit 2: Ion Transport to Shoot and Grains

- Long distance transport in plants - Mechanism of xylem and phloem transport, Radial movement of ions across the root
- Mechanism of phloem transport, remobilization of mineral nutrients - phloem loading, phloem unloading

Unit 3: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Macronutrients

- Molecular structures of LAT and HAT, their localization and regulation by various external factors
- Nitrate transporters and their functional regulation - Nitrate transporters

(NRT1, NRT2, dual-affinity nitrate transporter NRT1.1/CHL1)

- Phosphate transporters and their functional regulation - PT1/PHT1, PHT2, PHT3, PHT4
- Potassium transporters and their functional regulation - KT/HAK/KUP family
- Ion transporters involved in transport of multiple elements, for example, sulphate transporter for Selenate transport, phosphate transporter for Arsenate transport, etc.

Unit 4: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport

: Micro and Beneficial Nutrients

- Plant Strategies: Different Strategies I & II adopted by plants for uptake of Fe under Fe deficient condition
- Transporters and genes regulating uptake and transport of micronutrients, genes encoding transport/channel proteins, Examples of genes encoding mineral ion transporters for Zn, Fe, Mn, Cu, B, Mo, Ni, Cl, Na, Si, Se
- Beneficial nutrients and their role in plant growth and development – Sodium, Silicon, and Cobalt

Unit 5: Microbes, Fungal Association for Nutrient Acquisition

- Microbes to improve nutrient availability – Bio-inoculation technology- P solubilizers and Zinc solubilizers in nutrient absorption
- Microbial systems for biological nitrogen fixation – process of nodulation, biochemistry of N2-fixation
- Endophytes to improve nutrient availability, Mycorrhiza- Mycorrhizal symbiosis on nutrient uptake by root. Role of AMF on nitrogen, phosphorus and zinc uptake.

Unit 6: Nutrient Delivery

- Foliar application of nutrients, absorption and their compartmentation, Concept of slow release fertilizers and chelates (organic and inorganic)
- Soil less cultures- aeroponics, hydroponics, fertigation

BLOCK 3: NUTRIENT EFFICIENCY OF CROP

Unit 1: Improving Nutrient Acquisition and Efficiency of Crops

- Concept of nutrient uptake and use efficiency- Genotypic differences- physiology and molecular mechanisms, Nutrient use efficiency in selected crops
- Root system architecture (RSA), root characters associated with nutrient acquisition, Genes and QTLs to improve nutrient acquisition and efficiency for important nutrients in few crop species
- Transgenic and molecular breeding approaches to improve traits associated with acquisition and efficiency- Case studies
- Biofortification strategies – for micronutrients, agronomic approaches
- Influence of nutrition status on plant response to biotic and abiotic stresses

PRACTICALS

1. Techniques to develop the deficiency symptoms of nutrients – Hydroponics/Aeroponics- diagnosis of deficiency symptoms in agriculturally important crop plants

2 Physiological and biochemical markers to identify nutrient deficiency levels
3 Biochemical markers for essential elements: Assay of nitrate reductase activity for N
4 Estimation of chlorophyll concentration in leaves of N deficient and N sufficient plants
5 Collection of acid phosphatase from root exudates and enzyme assay for P
6 Measuring anthocyanin and chlorophyll pigments concentration in leaves for P
7 Collection of organic acid in root exudates, characterization and quantification for P
8 Assay of carbonic anhydrase activity for Zn
9 Assay of SOD Activity for Cu, Zn and Mn
10 Estimation of nitrogen concentration in plant tissue - Kjeldhal and Dumas method 11 Estimation of phosphorus concentration in plant tissue – colorimetric method
12 Estimation of potassium, magnesium and sodium concentration in plant tissue - flame photometer
13 Estimation of micronutrients (Zn, Cu, Fe, Mn, Co etc) concentration in plant tissue - atomic absorption spectrometer/ ICP-OES
14 Measurement of simple root traits such as root length, angle, volume, surface area, etc. (using conventional methods or root scanner and WinRhizo)
15 'Shovelomics' in the field grown crops (for measuring root architecture) and using 'ImageJ' for analysis
16 Non-invasive techniques to quantify nutrients – XRF (X-Ray Fluorescence) and hyper spectral reflectance

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

RESOURCES

Block 1: Unit I:

- Recommended Dietary Allowances: 10th Edition (https://www.ncbi.nlm.nih.gov/books/NBK234932/pdf/Bookshelf_NBK234932.pdf)
- da Silva Lobato, A.K., Lima, E.J.A., Lobato, E.M.S.G., Maciel, G.M. and Marques, D.J., 2016. Tolerance of Plants to Toxicity Induced by Micronutrients. In Abiotic and Biotic Stress in Plants-Recent Advances and Future Perspectives. IntechOpen.
- Renwick, A.G., 2006. Toxicology of micronutrients: adverse effects and uncertainty. The Journal of nutrition, 136(2), pp.493S-501S.
- Krämer, U., 2018. The Plants that Suck Up Metal. German Research, 40(3), pp.18-23.
- OroojSurriya, S.S.S., Waqar, K. and Kazi, A.G., 2014. Phytoremediation of soils: prospects and challenges. Soil remediation and plants: Prospects and challenges, p.1.

- Sarma, H., 2011. Metal hyperaccumulation in plants: a review focusing on phytoremediation technology. Journal of Environmental Science and Technology, 4(2), pp.118-138.

Unit 2:

- Mineral Nutrition of Higher Plants 3rd Edn– H. Marschner
- Plant Physiology Book by Eduardo Zeiger and Lincoln Taiz
- Book Chapter: Mineral Nutrition of Plants – Renu Pandey, In: Plant Biology and Biotechnology. B. Bahadur *et al*. (eds.), Volume I: Plant Diversity, Organization, Function and Improvement, DOI: 10.1007/978-81-322-2286-6_20, Springer India, Pp. 499-538.
- López-Arredondo, D.L., Leyva-González, M.A., Alatorre-Cobos, F. and Herrera- Estrella, L., 2013. Biotechnology of nutrient uptake and assimilation in plants. International Journal of Developmental Biology, 57(6-7-8), pp.595-610.

Block 2:

Unit 1:

- Sugita, R., Kobayashi, N.I., Hirose, A., Tanoi, K. and Nakanishi, T.M., 2019. Visualization of Ion Transport in Plants. In Agricultural Implications of the Fukushima Nuclear Accident (III) (pp. 221-231). Springer, Singapore.
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- Aibara, I. and Miwa, K., 2014. Strategies for optimization of mineral nutrient transport in plants: multilevel regulation of nutrient-dependent dynamics of root architecture and transporter activity. Plant and Cell Physiology, 55(12), pp.2027- 2036.

Unit 2:

- Barberon, M. and Geldner, N., 2014. Radial transport of nutrients: the plant root as a polarized epithelium. Plant physiology, 166(2), pp.528-537.
- De Schepper, V., De Swaef, T., Bauweraerts, I. and Steppe, K., 2013. Phloem transport: a review of mechanisms and controls. Journal of experimental botany, 64(16), pp.4839-4850.
- Comtet, J., Jensen, K.H., Turgeon, R., Stroock, A.D. and Hosoi, A.E., 2017. Passive phloem loading and long-distance transport in a synthetic tree-on-a-chip. Nature plants, 3(4), p.17032.

Unit 3:

- Regulation of Nutrient Uptake by Plants: A Biochemical and Molecular Approach – Gyanendra Nath Mitra
- Uraguchi, S., Kamiya, T., Sakamoto, T., Kasai, K., Sato, Y., Nagamura, Y., Yoshida, A., Kyozuka, J., Ishikawa, S. and Fujiwara, T., 2011. Low-affinity cation transporter (OsLCT1) regulates cadmium transport into rice grains. Proceedings of the national academy of sciences, 108(52), pp.20959-20964.
- William C. Plaxton and Hue T. Tran (2011) Metabolic Adaptations of Phosphate- Starved Plants. Plant Physiology, 156:1006–1015.

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- López-Arredondo, D.L., Sánchez-Calderón, L. and Yong-Villalobos, L., 2017. Molecular and genetic basis of plant macronutrient use efficiency: concepts, opportunities, and challenges. In Plant Macronutrient Use Efficiency (pp. 1-29). Academic Press.

Unit 4:

- Inostroza-Blancheteau, C., Aquea, F., Moraga, F., Ibañez, C., Rengel, Z. and Reyes- Díaz, M., 2017. Genetic Engineering and Molecular Strategies for Nutrient Manipulation in Plants. In Essential Plant Nutrients (pp. 405-441). Springer, Cham.
- Sperotto, R.A., Ricachenevsky, F.K., Williams, L.E., Vasconcelos, M.W. and Menguer, P.K., 2014. From soil to seed: micronutrient movement into and within the plant. Frontiers in plant science, 5, p.438.
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plants– a brief overview. Metallomics, 9(7), pp.813-823.

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Unit 5:

- Afzal, I (2019). "Plant beneficial endophytic bacteria: Mechanisms, diversity, host range and genetic determinants, Microbiological research
- Bertolazi A.A. *et al*. (2018) Linking Plant Nutritional Status to Plant-AMF Interactions. In: Egamberdieva D., Ahmad P. (eds) Plant Microbiome: Stress Response. Microorganisms for Sustainability, vol 5. Springer, Singapore
- Bhale, U. N., Bansode, S. A., and Singh, S. (2018). Multifactorial Role of ArbuscularMycorrhizae in Agroecosystem. Fungi and Their Role in Sustainable Development: Current Perspectives, 205–220.doi:10.1007/978-981-13-0393-7_12

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Unit 6:

- Lakhiar, I.A., Gao, J., Syed, T.N., Chandio, F.A. and Buttar, N.A., 2018. Modern plant cultivation technologies in agriculture under controlled environment: A review on aeroponics. Journal of Plant Interactions, 13(1), pp.338-352.
- Pradhan, B. and Deo, B., 2019. Soilless farming-the next generation green revolution. Current Science (00113891), 116(5).
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Block 3:

Unit 1:

- Reynolds, M.P., J.I. Ortiz-Monasterio, and A. McNab (eds.). 2001. Application of Physiology in Wheat Breeding. Mexico, D.F.: CIMMYT.
- The Molecular and Physiological Basis of Nutrient Use Efficiency in Crops –

Editors Malcolm J. HawkesfordandPeter Barraclough

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- Ferrante, A., Nocito, F.F., Morgutti, S. and Sacchi, G.A., 2017. Plant breeding for improving nutrient uptake and utilization efficiency. In Advances in Research on Fertilization Management of Vegetable Crops (pp. 221-246). Springer, Cham.
- Wang, Y. and Wu, W.H., 2015. Genetic approaches for improvement of the crop potassium acquisition and utilization efficiency. Current opinion in plant biology, 25, pp.46-52.
- Wan, T.E.N.G., Xue, H.E. and TONG, Y.P., 2017. Transgenic approaches for improving use efficiency of nitrogen, phosphorus and potassium in crops. Journal of integrative agriculture, 16(12), pp.2657-2673.
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- Heuer, S., Gaxiola, R., Schilling, R., Herrera-Estrella, L., López-Arredondo, D., Wissuwa, M., Delhaize, E. and Rouached, H., 2017. Improving phosphorus use efficiency: A complex trait with emerging opportunities. The plant journal, 90(5), pp.868-885.
- Garg, M., Sharma, N., Sharma, S., Kapoor, P., Kumar, A., Chunduri, V. and Arora, P., 2018. Biofortified crops generated by breeding, agronomy, and transgenic approaches are improving lives of millions of people around the world. Frontiers in nutrition, 5, p.12.
- Riaz, A., Abbas, A. and Raza, S., 2017. Techniques for the Enrichment of Micronutrients in Crops through Biofortification: A Review. Journal of Advances in Biology and Biotechnology, pp.1-7.

Credit: 2+1

Course Code: PP 507*

Title: PHOTOSYNTHETIC PROCESSES, CROP GROWTH AND PRODUCTIVITY AND CONCEPTS OF CROP MODELLING

WHY THIS COURSE?

Agronomic inputs and environmental factors enhance crop growth by improving photosynthetic processes and photosynthate partitioning. Carbon metabolism is the most important physiological process that has a direct influence on crop growth and productivity which is quite sensitive to biotic and abiotic constraints. Hence a comprehensive understanding canopy photosynthetic process is crucial. This is an important component in crop improvement program, especially in the scenario of plateauing yields. These photosynthetic processes and their response to environmental factors form the basis for developing growth and yield predicting models.

AIM OF THIS COURSE

The course provides a comprehensive theoretical and hands on experience and expertise to students on various aspects of photosynthesis including biophysical, biochemical and molecular regulations. While canopy photosynthesis drives crop growth rates, factors associated with sink activity and partitioning determine productivity. Hence, adequate emphasis would be given to canopy photosynthesis, translocation and its feedback regulation, Crop growth and yield structure analysis and their responses to environmental factors.

Growth and yield prediction models and their relevance will be adequately discussed.

The course is organized as follows:

No.	Blocks	Units
1.	**Photosynthetic Processes**	1. Canopy Architecture and Energy Utilization
		2. Photochemical Processes
		3. Biochemical Processes 4. Product Synthesis and Translocation
		5. Growth and Yield forming Mechanisms
2.	**Yield Improvement and Modelling**	1. Molecular Options to Improve Photosynthesis, Growth and Productivity
		2. Fundamentals of Dynamic Simulation Models
		3. Description of Well-established Yield Models
		4. Examples of Robust Models Extensively Used

LEARNING OUTCOMES

After completion of this course students are expected to have in depth knowledge on Photosynthetic processes associated with product synthesis and yield development. Students will also obtain current knowledge on various crop models.

BLOCK 1:PHOTOSYNTHETIC PROCESSES

Unit 1: Canopy Architecture and Energy Utilization

- Parameters associated with canopy architecture that determine radiation interception and absorption
- Energy absorption by primary and accessory pigments and energy utilization efficiency
- Light distribution inside the canopy and concepts of light extinction coefficient

Unit 2: Photochemical Processes

- Ultrastructure of chloroplast: structure and composition of lamellar system
- Components of electron transport, Water oxidation system and energy conservation processes
- Pigment systems and the generation of a powerful oxidant and a powerful reductant
- Chlorophyll fluorescence and fluorescence quenching: qN, qP, NPQ

Unit 3: Biochemical Processes

- CO2 diffusion and resistances (gs and gm). Concept of Ci determining CO2 diffusion.
- RuBisCO activation state, kinetics and catalytic properties
- Carboxylation processes in C3, C4 and CAM plants and their relevance
- CO2 concentrating mechanisms and their importance in improving carbon assimilation
- Ecological significance of C4 and CAM photosynthesis
- Photorespiration and Mitochondrial respiration and net carbon gain
- Carbon isotope discrimination and its importance as a surrogate of Ci

Unit 4: Product Synthesis and Translocation

- Triose phosphate utilization and regulation of Calvin cycle mechanisms
- Product synthesis and partitioning between starch and sucrose
- Concepts of end-product inhibition or Pi-regeneration limitation
- Phloem transport and factors that regulate phloem loading and un-loading

Unit 5: Growth and Yield forming Mechanisms

- Carbon gain and the concepts of Canopy photosynthesis. Relevance of LAI and LAD in determining total carbon gain and crop growth rates
- Source : Sink relationship and its relevance in governing differences in crop growth rates and productivity.
- Concepts of HI and partitioning coefficient and remobilization of carbon from vegetative organs to reproductive structures
- Growth analysis and parameters that explain growth rates: NAR, CGR, HI and their inter-dependence.

BLOCK 2: YIELD IMPROVEMENT AND MODELLING

Unit 1: Molecular Options to Improve Photosynthesis, Growth and Productivity

- Characteristic features of the Chloroplast genome: its structure and genes associated with various photosynthetic mechanisms, coordinated expression of chloroplast and nuclear genome for maintaining photosynthetic activities.
- Genomic and genetic resources such as specific genes and QTL associated with photosynthetic processes
- Transgenic options to enhance photosynthetic performance such as transferring genes to mitigate oxidative stress damage (SOD, APX, AKR etc)
- Theoretical concepts of crop improvement through inducing CCM in C3 plants and reducing photorespiration

Unit 2: Fundamentals of Dynamic Simulation Models

- Collection of crop specific genetic coefficient,
- Crop, soil and historic weather data

Unit 3: Description of Well-established Yield Models

- Application and limitations of modeling;
- Yield prediction models such as APSYM, PeanutGrowetc
- Machine learning approaches and IoT for making informed on-farm decisions

Unit 4: Examples of Robust Models Extensively Used

- Duncan'syield prediction model
- Passioura'smodelfor growth maximising

PRACTICALS

1. Plant sampling for leaf area and biomass estimation; analysis of growth and yield parameters – LAD, NAR. CGR, LAI, LAR, SLA portioning efficiency, HI.
2. Measurement of light interception, light extinction coefficient, energy utilization efficiency based energy intercepted, and realized.
3. Gas exchange: principles and uses to assess variations in CO2 and water vapour transfer, determination of A/gs and intrinsic WUE
4. Quantification of chlorophyll content by various methods: colorimetric and SPAD meter. The concept of SLN
5. Chlorophyll fluorescence and quenching coefficients
6. Theoretical aspects of carbon isotope fractional and its use in determining WUE
7. Quantification of RuBisCO content by ELISA (if possible)
8. Determination of RuBisCO activity and activation state using radioactive CO2
9. CO2 and light response curves and computation of carboxylation efficiency, quantum efficiency, relative limitations of photosynthesis at single leaf level.
10. Adoption of crop models: Growth and yield prediction by Duncan's and Passioura's models

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

RESOURCES

Block 1:

Unit 1:

- Goyne, P. J., Milroy, S. P., Lilley, J. M., and Hare, J. M. (1993). Radiation interception, radiation use efficiency and growth of barley cultivars. *Australian Journal of Agricultural Research*, *44*(6), 1351-1366.
- https://www.sciencedirect.com/topics/chemistry/photosynthetic-pigment.
- Frank, H. A., Young, A., Britton, G., and Cogdell, R. J. (Eds.). (2006). *The photochemistry of carotenoids* (Vol. 8). Springer Science and Business Media.

Unit 2:

- Ruban, A. V. (2016). Nonphotochemical chlorophyll fluorescence quenching: mechanism and effectiveness in protecting plants from photodamage. *Plant Physiology*, *170*(4), 1903-1916.
- Maxwell, K., and Johnson, G. N. (2000). Chlorophyll fluorescence—a practical guide. *Journal of experimental botany*, *51*(345), 659-668.
- https://www.researchgate.net/publication/38051229,_The_photochemical_reaction_in _photosynthesis.

Unit 3:

- Wang, Y., Stessman, D. J., and Spalding, M. H. (2015). The CO2 concentrating mechanism and photosynthetic carbon assimilation in limiting CO2: how Chlamydomonas works against the gradient. *The Plant Journal*, *82*(3), 429-448.
- Dietz, K. J., and Pfannschmidt, T. (2011). Novel regulators in photosynthetic redox control of plant metabolism and gene expression. *Plant Physiology*, *155*(4), 1477- 1485.
- Farquhar, G. D., Ehleringer, J. R., and Hubick, K. T. (1989). Carbon isotope discrimination and photosynthesis. *Annual review of plant biology*, *40*(1), 503-537.

Unit 4:

- Paul, M. J., and Foyer, C. H. (2001). Sink regulation of photosynthesis. *Journal of experimental botany*, *52*(360), 1383-1400.
- De Schepper, V., De Swaef, T., Bauweraerts, I., and Steppe, K. (2013). Phloem transport: a review of mechanisms and controls. *Journal of experimental botany*, *64*(16), 4839-4850.

Unit 5:

- Weraduwage, S. M., Chen, J., Anozie, F. C., Morales, A., Weise, S. E., and Sharkey,

  T. D. (2015). The relationship between leaf area growth and biomass accumulation in Arabidopsis thaliana. *Frontiers in plant science*, *6*, 167.
- Hay, R. K. M. (1995). Harvest index: a review of its use in plant breeding and crop physiology. *Annals of applied biology*, *126*(1), 197-216.
- Irving, L. (2015). Carbon assimilation, biomass partitioning and productivity in grasses. *Agriculture*, *5*(4), 1116-1134.

Block 2:

Unit 1:

- de Freitas Lima, M., Eloy, N. B., de Siqueira, J. A. B., Inzé, D., Hemerly, A. S., and Ferreira, P. C. G. (2017). Molecular mechanisms of biomass increase in plants. *Biotechnology Research and Innovation*, *1*(1), 14-25.
- Raines, C. A. (2011). Increasing photosynthetic carbon assimilation in C3 plants to improve crop yield: current and future strategies. *Plant physiology*, *155*(1), 36-42.
- vonCaemmerer, S., and Evans, J. R. (2010). Enhancing C3 photosynthesis. *Plant Physiology*, *154*(2), 589-592.

Unit 2:

- http://ijid.informaticspublishing.com/index.php/ijid/article/download/111838/78332
- https://www.mdpi.com/1424-8220/18/8/2674/pdf

Unit 3:

- http://ijid.informaticspublishing.com/index.php/ijid/article/download/111838/78332
- https://www.mdpi.com/1424-8220/18/8/2674/pdf

Unit 4:

- Splinter, W. E. (1974). Modelling of plant growth for yield prediction. *Agricultural Meteorology*, *14*(1-2), 243-253.

General Source Information:

- Molecular mechanisms of Photosynthesis 2nd Edition 2014 by Robert E Blankenship
- Canopy Photosynthesis: From Basics to Applications. 20165 Editors: Hikosaka, Kouki, Niinemets, Ülo, Anten, Niels P.R.
- The Leaf: A Platform for Performing Photosynthesis. 2018. Editors: AdamsIII, William W., Terashima, Ichiro.
- Handbook of Photosynthesisn3rd Edition. 2016. Mohammad Pessarakli

Credit : 2+0
Course Code : PP 508
Title : PHYSIOLOGY OF FIELD CROPS

WHY THIS COURSE?

In recent years, phenomenal progress has been made in understanding plant processes which are crop specific. Genetic gain in productivity can be achieved only by improving plant physiological traits/adaptive mechanisms. Even crop management should be based on sound physiological principles. For example, crop's response to the increase in global warming has to be looked from thermo morphogenesis concept in terms of GDD and its effect on phenological processes in some of the important field crops exposure on crop specific physiological processes is necessary and has particular significance.

AIM OF THIS COURSE

This course provides a broad exposure on the physiological aspects of field crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of field crop plants. Besides, the emphasis is on unique crop specific features.

Broad categories of crops that can be selected for this course are as follows.

1. Cereals – Rice, Wheat, Maize etc.
2. Millets – Finger millet, Sorghum etc.
3. Pulse crops- Green gram, Black gram, Lentil, Pigeon pea, Chickpeas, Cowpea, Beans etc.
4. Oilseed crops – Groundnut, Rapeseed Mustard, Soybean etc.
5. Sugarcane
6. Fibre crops- Cotton, Jute, Ramie, Hemp etc.

The course is organized as follows:

No.	Blocks	Units
1.	**Physiology of Field Crops**	1. Introduction
		2. Crop Establishment, Crop Growth and Development
		3. Reproductive Growth
		4. Seed Nutrient Quality
		5. Plant Nutrition
		6. Abiotic Stress Response
		7. Crop Specific Physiological Processes and Importance

LEARNING OUTCOMES

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of field crops.

BLOCK 1: PHYSIOLOGY OF FIELD CROPS

Unit 1: **Introduction**

- Origin- Variability in physiology of crop plants between wild species and cultivated. Adaptability to growing environments (ecosystems), Importance in food grain contribution

Unit 2: **Crop Establishment, Crop Growth and Development**

- Seed characteristic features, dormancy, viability, concept of seed priming seedling establishment and crop stand
- Different crop growth stages, concept of source establishment and optimum LAI, Canopy architecture, light interception/radiation use efficiency, thermal time, heat units, GDD, determining growth duration.

Unit 3: Reproductive Growth

- Photo and thermo-periodic response for flowering, sink development, sink source relationship, partitioning efficiency, improvement in HI, yield determining factors, genetic gain in yield over years, structuring of ideal plant type, limitations to improve source to sink size, options to improve yield potential

Unit 4: Seed Nutrient Quality

- Seed quality, seed as a source of nutrients, seed constituents and their improvement, concept of pathway engineering to improve seed quality

Unit 5: Plant Nutrition

- Nutrient requirement, genetic variability in nutrient acquisition under constraint conditions, specific nutrient disorders

Unit 6: Abiotic Stress Response

- Response to different abiotic stresses, plant traits/mechanics to improve adaptation to realize potential yields.

- Global warming responses, thermomorphogenesis, approaches to overcome the constraints.

Unit 7: Crop Specific Physiological Processes and Importance

- Choosing location specific crop species exposure will be given on physiological process as described above. Besides, emphasis is on providing information on crop specific features/productivity constraints

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

Pulses:

- Grain Legumes: Editors: **De Ron**, Antonio M. (Ed.) 2015. Springer
- **Legumes under Environmental Stress: Yield, Improvement and Adaptations.** Edited by M.M Azooz and P. Ahmad, Hoboken, NJ: John Wiley and Sons, Ltd., 328 pages. ISBN:978-1-118-91708-4
- Pulse Crops: Biotechnological Strategies to Enhance Abiotic Stress Tolerance .S. Ganeshan P. M. Gaur R. N. ChibbarDr. Narendra Tuteja Dr. Sarvajeet Singh Gill Dr. RenuTuteja chapter 17
- Climate Change and Management of Cool Season Grain Legume Crops . Edited by Shyam Singh Yadav, David L. McNeil, Robert Redden, Sharanagouda A. Patil Springer
- Nature’s pulse power: legumes, food security and climate change. Michael J. Considine, Kadambot H.M. Siddique, and Christine H. Foyer · J Exp Bot. 2017 Apr 1; 68(8): 1815–1818. Published online 2017 May 11. doi: 10.1093/jxb/erx099

Sugarcane:

- Glassop D, Rae AL and Bonnett GD (2014) Sugarcane flowering genes and pathways in relation to vegetative regression. Sugar Tech. 16(3): 235-240. DOI 10.1007/s12355-013-0284-z
- McCormick AJ, Watt DA and Cramer MD (2009) Supply and demand: sink regulation of sugar accumulation in sugarcane. Journal of Experimental Botany. 60(2): 357-364. DOI 10.1093/jxb/em310
- Moore PH and Botha FC (2014) Sugarcane: physiology, biochemistry, and functional biology. John Wiley and Sons ISBN 978-1-118-77119-8
- Ram B, RajulaShanthy T, Viswanathan R, Hemaprabha G and Palaniswami C (2016) Handbook on sugarcane. ICAR-Sugarcane Breeding Institute. ISBN 978-93-85267- 03-1
- Shrivastava AK, Solomon S, Rai RK, Singh P, Chandra A, Jain R and Shukla SP (2015) Physiological interventions for enhancing sugarcane and sugar productivity. Sugar Tech. 17(3): 215-226. DOI 10.1007/s12355-014-0321-6

Maize:

- Evans, L.T., 1996. Crop Evolution, Adaptation and Yield. Cambridge University Press.
- Jeff L. Bennetzen, j.l AND Hake, S.C. (2009) Hand Book of Maize: Its Biology, Springer-Verlag New York
- Singh, C.B.andKhare, D. (2015). Genetic Improvement of Field Crops. Scientific Publishers, Jodhpur.
- Tollenaar M., Dwyer L.M. (1999) Physiology of Maize. In: Smith D.L., Hamel C. (eds) Crop Yield. Springer, Berlin, Heidelberg

Rice

- Yoshida, S., 1981. Fundamentals of Rice Crop Science. IRRI.
- Rehman, Abdul. (2016). Photosynthesis under heat stress. Handbook of Photosynthesis, Edition: Third Edition, Publisher: CRC Press Taylor and Francis Group, pp.697-701.
- Negrão S, Courtois B, Ahmadi N, Abreu I, Saibo N, Oliveira MM (2011) Recent updates on salinity stress in rice from physiological to molecular responses. Crit Rev Plant Sci 30:329-377
- Von Caemmerer, S., Quick, W.P. and Furbank, R.T., 2012. The development of C4 rice: current progress and future challenges. science, 336(6089), pp.1671-1672.
- S. Hubbart S. Peng P. Horton Y. Chen E. H. Murchie. Trends in leaf photosynthesis in historical rice varieties developed in the Philippines since 1966;Journal of Experimental Botany, 2007**,** Vol. 58 (12), 3429–3438
- Fahad S, Bajwa AA, Nazir U, Anjum SA, Farooq A, Zohaib A, Sadia S, Nasim W, Adkins S, Saud S and Ihsan MZ (2017) Crop production under drought and heat stress: plant responses and management options. Frontiers in Plant Science 8(1147):1-16.
- Pandey V and Shukla A (2015) Acclimation and Tolerance Strategies of Rice under Drought Stress. Rice Science 22(4):147-161.

Cereals and Millets:

- Kole, Chittaranjan. 2006. Cereals and millets
- Samuel A. Matz. 2006. Cereal science

Wheat:

- Rinki, Mamrutha HM, Sareen Sindhu, Tiwari Vinod, Singh GP 2018. Dissecting the physiological and anatomical basis for high yield potential in HD 2967. Vegetos. 31: 121-124.
- Kumar R, Kaur A, Ankita P, Mamrutha HM, Singh GP 2019. CRISPR based genome editing in wheat: A comprehensive review and future prospects. Molecular biology reports10.1007/s11033-019-04761-3
- R.Tiwari and H.M.Mamrutha. 2014. Precision Phenotyping for Mapping of Traits for Abiotic Stress Tolerance in Crops. Biotechnology: Prospects and Applications. Editors. R.K. Salar, S.K. Gahlawat, P. Siwach and J.S. Duhan. Pp79-85. Publisher: Springer.

- Wheat Physiological Breeding II: A Field Guide to Wheat Phenotyping. (CIMMYT publication)
- Breeding for field crops book by David Allen Sleper and john Milton Poehlman
- Wheat Physiological Breeding volume I and II by Mathew Reynolds from (CIMMYT): Wheat Physiological Breeding: A Field Guide to Wheat Phenotyping.
- Mamrutha H.M. *et al*. (2019) Physiological and Molecular Basis of Abiotic Stress Tolerance in Wheat. In: Rajpal V., Sehgal D., Kumar A., Raina S. (eds) Genetic Enhancement of Crops for Tolerance to Abiotic Stress: Mechanisms and Approaches, Vol. I. Sustainable Development and Biodiversity, vol 20. Springer, Cham
- Tiwari V. *et al*. (2017) Managing Abiotic Stresses in Wheat. In: Minhas P., Rane J., Pasala R. (eds) Abiotic Stress Management for Resilient Agriculture. Springer, Singapore

Credit: 2+0

Course Code: PP 509

Title: PHYSIOLOGY OF HORTICULTURE CROPS

WHY THIS COURSE?

Improving physiological processes forms the basis to enhance the productivity or to improve a specific growth processes. Several interventions based on principals of physiological processes provide options to enhance crop productivity. Basic insight on photoperiodic response is crucial for determining planting dates. Understanding the mechanisms of rooting for vegetative propagation has lead in developing rooting hormones etc., In view of this, a comprehensive exposure on growth and development of horticulture crops and providing insights on major production constraints and physiological approaches to overcome is highly essential.

AIM OF THIS COURSE

This course should provide a broad exposure on the physiological aspects of horticulture crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of horticultural crop plants. To describe basic and applied physiology behind the production and productivity of horticultural crops and their pre and postharvest management, ideal storage conditions, quality retention, processing and value addition.

Broad categories of crops that can be selected for this course are as follows.

1. Fruit crops: Mango, Grapes, Apple, Banana, Citrus etc.
2. Vegetable crops: Tomato, Onion, Brinjal, Cauliflower, Okra etc.
3. Tuberous crops: Potato, Cassava, Sweet potato, Yam etc.
4. Plantation crops: Coconut, Oil palm, Cashew, Tea, Coffee, Rubber, Areca nut, Cocoa etc.
5. Floriculture crops: Rose, Marigold, Carnation, Chrysanthemum, Gladiolus,

Orchids, Tuberose etc.

6. Other groups: Medicinal crops, Aromatic crops, Spices crops.

The course is organized as follows:

No.	Blocks	Units
1	**Physiology of Horticultural Crops**	1. Introduction
		2. Crop growth and Development
		3. Reproductive Growth
		4. Pre and Post-harvest Physiology
		5. Plant Nutrition and Abiotic Stress Responses
		6. Specific Aspects and Unique Crop Features

LEARNING OUTCOMES

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of horticultural crops.

BLOCK 1: PHYSIOLOGY OF HORTICULTURAL CROPS

Unit 1: Introduction

- Origin, distribution and adaptability of crops to different agro-climatic conditions

Unit 2: Crop growth and Development

- Internal factors (hormone etc.) influencing various physiological processes linked to vegetative growth or growth of specific organ, correlative and algometric growth\
- External factors (water, nutrition, temperature etc.) influencing various physiological processes linked to vegetative growth or growth of specific organ, correlative and algometric growth
- Propagation methods, grafting, cutting, budding, air layering. Physiology of pruning, dwarfing, branch bending, canopy management etc
- Physiological and biochemical aspects of scion and root stock interaction and compatibility

Unit 3: Reproductive Growth

- Physiology of flowering, photo- and thermo-periodism and response to vernalization
- Factors influencing reproductive growth, fruit and seed set/retention, physiology of flower sex ratio
- Physiological processes governing source-sink relationship and productivity.

Unit 4: Pre and Post Harvest Physiology

- Preharvest factors influencing postharvest physiology
- Physiological and molecular mechanisms of ripening
- Physiological and molecular mechanisms of senescence

- Hormonal and chemical control of postharvest deterioration of fruits/vegetable/flowers
- Regulation of ripening at physiological and molecular levels
- Regulation of senescence at physiological and molecular levels
- Approaches to improve shelf life and storability
- Approaches to improve postharvest management
- Approaches to improve processing and value addition

Unit 5: Plant Nutrition and Abiotic Stress Responses

- Nutrient acquisition and requirement, plant phenology and nutrient requirement
- Role of rootstocks in nutrient acquisition and in abiotic stress tolerance.
- Adaptive mechanisms and approaches to improve performances under drought and high temperature
- Adaptive mechanisms and approaches to improve performances under frost, chilling and nutrient deficient conditions
- Root physiology in abiotic stress tolerance

Unit 6: Specific Aspects and Unique Crop Features Specific aspects:

- Polyhouse cultivation
- Hormones/PGRs for improving crop performance
- Major and micronutrients for improving crop performance
- Light interception, shade regulation, dwarfing root stocks
- Chilling requirement for flowering, photoperiodic response, pollen viability, stigma receptivity
- Flower (blossom) and fruit drop

Unique crop features:

- Maturity and maturity indices
- Source-sink relations
- Vegetative propagation,
- Physiology of tuberization and rhizome initiation and formation
- Virus free planting material
- Bulbs/tubers dormancy, bud break
- Physiological disorders
- Storage
- Packaging
- Quality

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

Block 1:

Books

- M. R. Sethuraj and A. S. Raghavendra, Tree Crop Physiology, ISBN-13:978- 0444428417, ISBN-10:0444428410, Elsevier Science Publishers. B. V. (2012)
- Dhillon/Bhatt, Fruit Tree Physiology, ISBN-10: 9380428421, ISBN-13: 978- 9380428420 Narendra Publishing House (2012),
- Prerak Bhatnagar, Physiology of Growth and Development of Horticultural Crops, ISBN-10:817754666X, ISBN-13: 978-8177546668
- Amar Singh, Fruit Physiology and Production, ISBN-10: 8127211788, ISBN-13: 978- 8127211783, Kalyani Publishers; 5th edition (March 28, 2003).
- Krishna Hare, Physiology of Fruit Production, ISBN-10:9380012373, ISBN-13:978- 9380012377, Studium Press India Pvt. Ltd (2012)
- Edward F. Durner, Principles of Horticultural Physiology, ISBN-13: 978- 1780643069, ISBN-10:1780643063, CABI (June 3, 2013)
- J. K. A. Bleasdale, Plant Physiology in Relation to Horticulture, ISBN-10: 8192686094, ISBN-13:978-8192686097, SENTIFIC (2014) 2nd edition
- Dr. Mukul Kumar, Physiology of Fruit Production, ISBN-10:9384568384, ISBN- 13:978-9384568382, Year- 2015
- ElhadiM.Yahia and Armando Carrillo-Lopez, Postharvest Physiology and Biochemistry of Fruits and Vegetables, ISBN-10:0128132787, ISBN-13:978- 0128132784, Woodhead Publishing (7 November 2018).
- Sergio Tonetto de Freitas and Sunil Pareek, Postharvest Physiological Disorders in Fruits and Vegetables, ISBN-9781138035508, 1138035505,Taylor and Francis Ltd

Crop Specific information:

Mango

- Dhillon, W.S. and Bhat, Z.A., 2011. Fruit tree physiology. Narendra Publishing House.
- Sandip, M., Makwana, A.N., Barad, A.V. and Nawade, B.D., 2015. Physiology of flowering–the case of mango. Int. J. Appl. Res, 1(11), pp.1008-1012.
- Schaffer, B. and Andersen, P.C., 2018. Handbook of environmental physiology of fruit crops. CRC Press.
- Lakshminarayana, S., Subhadra, N.V. and Subramanyam, H., 1970. Some aspects of developmental physiology of the mango fruit. Journal of Horticultural Science, 45(2), pp.133-142.
- SWAMY, J.S., 2012. Flowering manipulation in mango: A science comes of age. Journal of Today's Biological Sciences: Research and Review, New Delhi, 1(1), pp.122-137.

- Singh, V.K. and Sharma, K., 2008. Physiological and biochemical changes during flowering of mango (mangifera indica l.). International Journal of Plant Developmental Biology, 2(2), pp.100-105.
- Carr, M.K.V., 2014. The water relations and irrigation requirements of mango (Mangifera indica L.): a review. Experimental agriculture, 50(1), pp.1-23.
- Hagemann, M.H., Roemer, M.G., Kofler, J., Hegele, M. and Wünsche, J.N., 2014. A new approach for analysing and interpreting data on fruit drops in mango. HortScience, 49(12), pp.1498-1505.
- Ramírez, F. and Davenport, T.L., 2010. Mango (Mangifera indica L.) flowering physiology. Scientia Horticulturae, 126(2), pp.65-72.
- Léchaudel, M., Lopez-Lauri, F., Vidal, V., Sallanon, H. and Joas, J., 2013. Response of the physiological parameters of mango fruit (transpiration, water relations and antioxidant system) to its light and temperature environment. Journal of plant physiology, 170(6), pp.567-576.
- Urban, L., Jegouzo, L., Damour, G., Vandame, M. and François, C., 2008. Interpreting the decrease in leaf photosynthesis during flowering in mango. Tree physiology, 28(7), pp.1025-1036.
- Jameel, M.A., Naik, S.R., Madhumathi, C., Reddy, D.S. and Venkataramana, K.T., 2018. Physiology of flowering in mango. Journal of Pharmacognosy and Phytochemistry, 7(6), pp.2375-2382.
- Lin, H.L., Shiesh, C.C. and Chen, P.J., 2012, May. Physiological disorders in relation to compositional changes in mango (Mangiferaindica L.'Chiin Hwang') fruit. In VII International Symposium on Mineral Nutrition of Fruit Crops 984 (pp. 357-363).
- Dayal, V., Dubey, A.K., Singh, S.K., Sharma, R.M., Dahuja, A. and Kaur, C., 2016. Growth, yield and physiology of mango (Mangifera indica L.) cultivars as affected by polyembryonic rootstocks. Scientia horticulturae, 199, pp.186-197. Grapes
- Keller, M., 2015. The science of grapevines: anatomy and physiology. Academic Press.
- Williams, L.E., 2017. Grape. In Photoassimilate Distribution Plants and Crops Source-Sink Relationships (pp. 851-882). Routledge.
- Symons, G.M., Davies, C., Shavrukov, Y., Dry, I.B., Reid, J.B. and Thomas, M.R., 2006. Grapes on steroids. Brassinosteroids are involved in grape berry ripening. Plant physiology, 140(1), pp.150-158.
- Balint, G. and Reynolds, A.G., 2013. Impact of exogenous abscisic acid on vine physiology and grape composition of Cabernet Sauvignon. American journal of enology and viticulture, 64(1), pp.74-87.
- Srinivasan, C. and Mullins, M.G., 1981. Physiology of flowering in the grapevine—a review. American Journal of Enology and Viticulture, 32(1), pp.47-63.
- Lebon, G., Wojnarowiez, G., Holzapfel, B., Fontaine, F., Vaillant-Gaveau, N. and Clément, C., 2008. Sugars and flowering in the grapevine (Vitis vinifera L.). Journal of experimental botany, 59(10), pp.2565-2578.

- Owais, S.J., 2015. Morphological and physiological responses of six grape genotypes to NaCl salt stress. Pakistan Journal of Biological Sciences, 18(5), p.240.
- Kondo, S. and Fukuda, K., 2001. Changes of jasmonates in grape berries and their possible roles in fruit development. *Scientia Horticulturae*, *91*(3-4), pp.275-288.
- CooMbe, B.G. and McCarthy, M.G., 2000. Dynamics of grape berry growth and physiology of ripening. *Australian journal of grape and wine research*, *6*(2), pp.131- 135.
- Chervin, C., El-Kereamy, A., Roustan, J.P., Latché, A., Lamon, J. and Bouzayen, M., 2004. Ethylene seems required for the berry development and ripening in grape, a non-climacteric fruit. *Plant Science, 167*(6), pp.1301-1305.

Guava

- Rodrigues, A.A.M., Silva, S.D.M., Dantas, A.L., Silva, A.F.D., Santos, L.D.S. and Moreira, D.D.N., 2018. Physiology and postharvest conservation of 'Paluma'guava under coatings using Jack fruit seed-based starch. RevistaBrasileira de Fruticultura, 40(2).
- Srivastava, H.C. and Narasimhan, P., 1967. Physiological studies during the growth and development of different varieties of guavas (Psidiumguajava L.). Journal of Horticultural Science, 42(1), pp.97-104. Singh, S.K., Malhotra, S.K., Bhargava, R., Singh, R.S. and Shukla, A.K., 2017
- Morphological and physiological characterization of guava (Psidiumguajava) under hot-arid zone of Rajasthan. Indian Journal of Agricultural Sciences, 87(4), pp.491-5.
- Mondal, K., Malhotra, S.P., Jain, V. and Singh, R., 2009. Oxidative stress and antioxidant systems in Guava (Psidiumguajava L.) fruits during ripening. Physiology and Molecular Biology of Plants, 15(4), p.327.
- Adhikari, S. and Kandel, T.P., 2015. Effect of time and level of pruning on vegetative growth, flowering, yield, and quality of guava. *International journal of fruit science*, *15*(3), pp.290-301.
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  - Patel, R.K., Maiti, C.S., Deka, B.C., Deshmukh, N.A., Verma, V.K. and Nath, A., 2015. Physical and biochemical changes in guava (Psidiumguajava L.) during various stages of fruit growth and development.
  - Guava Pruning and Its Physiology 2012 Shiva Adhikari

Tomato

- Aivalakis, G. and Katinakis, P., 2008. Biochemistry and molecular physiology of tomato and pepper fruit ripening. *Eur J Plant SciBiotechnol*, *2*(special issue 1), pp.145-155.

- Peet, M.M., 2008, September. Physiological disorders in tomato fruit development. In

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- Fentik, D.A., 2017. Review on genetics and breeding of tomato (Lycopersicon esculentum Mill.). *Adv Crop Sci Tech*, *5*(5), p.306.

Onion

- Brewster, J.L., 2018. Physiology of crop growth and bulbing. In Onions and allied crops (pp. 53-88). CRC Press.
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- Brewster, J.L., 1994, March. Environmental physiology of the onion: towards quantitative models for the effects of photoperiod, temperature and irradiance on bulbing, flowering and growth. In I International Symposium on Edible Alliaceae 433 (pp. 347-374).
- Coolong, T.W., 2007. Physiological Factors Affecting Onion (Allium Cepa L.) Storability: Cultural Methods for Improving Postharvest Quality (Doctoral dissertation, University of Georgia).
- Khokhar, K.M., 2017. Environmental and genotypic effects on bulb development in onion–a review. The Journal of Horticultural Science and Biotechnology, 92(5), pp.448-454.
- Khokhar, K.M., 2014. Flowering and seed development in onion—A review. Open Access Library Journal, 1(07), p.1.

Brinjal

- Sharma, S.P. and Brar, J.S., 2008. Nutritional requirements of brinjal (Solanummelongena L.)-A review. Agric. Rev, 29(2), pp.79-88.
- Byari, S.H. and Al-Rabighi, S.M., 1995. Morphological and physiological responses of eggplant cultivars (Solanummelongena L.) to drought. *J. KAU: Met. Env, Arid Land Agric. Sci*, *6*, pp.41-47.

Credit	**:**	**2+1**
Course Code	**:**	**PP 510**
Title	**:**	**SEED PHYSIOLOGY**

WHY THIS COURSE?

Seeds are considered as propagule and as a major source of nutrition for humans and other animals. Therefore, all information concerning their nutritive value, chemical composition; storability, retention of viability are very important. Looking into the importance of seeds, emphasis has been given to produce high quality seeds with excellent genetic potential to improve seed germination and to produce vigorous seedlings. In fact, recently techniques are employed to raise healthy and vigorous seeds to obtain vigorous seedlings. Several hormones and chemicals are used to improve the oil, protein, and other economic attributes of seeds. Therefore, to give more insight into the development of quality seeds and also protecting them without losing much of nutritive value, this course has been proposed.

AIM OF THIS COURSE

This course will approach the subjects from two perspectives –physiology of seed development and seed germination. It aims to describe students the physiological processes involved in regulation and mechanism of seed development, dormancy and germination. Further, to provide an insight into physiological processes governing seed quality and its survival. Accordingly, the course is organized as follows:

No.	Blocks	Units
1.	**Physiology of Seed Development**	1. Introduction to Seed Physiology
		2. Seed Development
		3. Seed Maturation
		4. Metabolism in Developing Seed
2.	**Physiology of Seed Germination and Dormancy**	1. Seed Germination
		2. Seed Dormancy and Viability

LEARNING OUTCOMES

At the end of the course the students are expected to be able to understand the physiology of seed development and seed germination. The students will be able to identify the physiological processes involved in regulation of seed development, dormancy and germination.

BLOCK 1: PHYSIOLOGY OF SEED DEVELOPMENT

Unit 1: Introduction to Seed Physiology

- Importance of seed as a propagule, seed structure and functions; chemical composition of seeds. Embryogenesis: pollination and fertilization, pollen and pistil interaction, signal for interaction; pollen load hypothesis; genetical and environmental influence on seed development.
- Source-Sink relationship affecting seed yield and quality.
- Concept of seed viability and seedling vigour and their relevance; approaches to improve the storability of seeds
- Physiological and molecular mechanisms of seed germination; approaches to improve seed germination; seed size and its influence on seed germination

Unit 2: Seed Development

- Physiology and molecular mechanisms of embryo, endosperm and seed coat development; cellularization during endosperm development; morphological and cellular changes

  during seed coat development, anatomy and function of seed coat, programmed cell death (PCD) in seed coat, Deposition of seed storage reserves during development

Unit 3: Seed Maturation

- Seed maturation and maturation indices; physiological and anatomical changes during seed maturation;
- Seed drying and acquisition of desiccation tolerance in seeds; mechanisms of desiccation tolerance; role of ABA LEA's, HSP's, dehydrins and other stress proteins during seed maturation and drying,
- Seed abortion and approaches to reduce it.

Unit 4: Metabolism in Developing Seed

- Chemical composition of seeds (carbohydrates, proteins, fats etc.), source of assimilates for seed development, pathways of movement of assimilates to developing seed, approaches to increase the chemical composition of seeds.
- Seed respiration and mitochondrial activity; seed respiration rate and storability of seeds.
- Seed ageing, Mobilization of stored resource in seeds; Chemistry of oxidation of starch, proteins and fats; Utilization of breakdown products by embryonic axis.

BLOCK 2: PHYSIOLOGY OF SEED GERMINATION AND DORMANCY

Unit1: Seed germination

- Seed germination, types of germination, imbibition kinetics of germinating seed; Physiological events during germination: seed respiration, mitochondrial activity, mobilization of food reserve; energy utilization by the germinating seed.
- Environmental regulation of germination: hydro-time, thermal time and hydrothermal time models; Influence of environmental factors on germination; Role of plant hormones/PGR's during seed germination.

Unit 2 :Seed Dormancy and Viability

- Physiological and molecular basis of seed dormancy, hormonal regulation of dormancy, After ripening, dormancy breaking treatments; Ecological perspective of seed dormancy.
- Seed viability: concept and physiology of seed viability, theories of seed ageing, seed storage and regulation of storage life of seeds; methods to prolong seed viability; Conservation of orthodox and recalcitrant seeds
- Seed vigour: concept, importance, measurement; Physiological, biochemical and molecular basis of seed vigour

PRACTICALS

1. Determination of seed reserves: carbohydrates, proteins and lipids
2. Study of different seed structures
3. Kinetics of seed imbibition; Seed germination test, enzymatic activities and respiration during germination and vigour testing methods etc.
4. Accelerated ageing test to know the seed vigour and storability
5. Measurement of seed moisture content
6. Determination of amylase activity in germinating seeds
7. Measurement of electrical conductivity in seed leachate
8. Measurement of seed viability using tetrazolium chloride

9. Determination of dehydrogenase activity
10. Seed germination study- Determination of Germination Index and seedling growth
11. Measurement ofseed vigour index
12. Dormancy breaking treatments
13. Seed priming techniques
14. Effect of environmental stresses on seed germination and seedling growth
15. Effect of hormones on seed germination

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

- Bewley, JD, Bradford K,,Hilhorst H, Nonogaki H. (2013). Seeds: Physiology of Development, Germination and Dormancy, Springer-Verlag
- Larkins BA and Vasil IK (Ed), Cellular and Molecular Biology of Plant Seed Development, 2010, Springer
- Vanangamudi K, Natarajan K and Vanangamudi M, Seed Physiology, Associated Publishing Company
- Bewley JD and Black M, 1994 Seeds: Physiology of Development and Germination, Springer
- N.W. Pammenter and Patricia Berjak (2000). Aspects of recalcitrant seed physiology. R.Bras. Fisiol. Veg., 12: 56-69.
- Prakash. M. 2011. Seed physiology of crops.(ed). Satish Serial Publishing house, New Delhi.
- Roberto Benech-Arnold, Rodolfo Sanchez. 2004. Handbook of Seed Physiology: Applications to Agriculture. CRC Press .
- Vijayakumar, A. 2001. Seed Dormancy an overview. In : Recent techniques and Participatory Approachs in Quality seed production (eds. K. Vanangamudi*et al*.,) TNAU, Coimbatore. pp 287-396.
- Padmavathi, S., M. Prakash, S. Ezhil Kumar, G. Sathianarayanan and A.Kamaraj. 2012. A Text Book of Seed Science and Technology. New India Publishing Agency, New Delhi.
- Tina Steinbrecher Gerhard Leubner-Metzger (2017). The biomechanics of seed germination**.** *Journal of Experimental Botany*, 68(4): 765–783.
- http://sbc.ucdavis.edu/Research_pages/Seed_physiology_and_technology/.
- Bench ALR and Sanchez RA. 2004. Handbook of Seed Physiology. Food Product Press.

Credit : 2+0

Course Code : PP 511

Title: PHENOTYPING PHYSIOLOGICAL PROCESSES

WHY THIS COURSE?

One of the main mandates of SAU and crop specific institutes is crop improvement. Seed industry and academic institutes need contribution from physiologists on these aspects. Conceptual changes in breeding approaches in terms of breeding for specific physiological traits necessitates that the students develop conceptual approaches for phenotyping in different physiological processes. Characterizing the parents, germplasm accessions, segregating populations for specific physiological traits like flowering response, variation in root system architecture, etc is crucial for genetic enhancement of these traits. This student ready Course can contribute richly to research and development of the seed sectors and crop specific institutions where the major emphasis in recent years is genetic enhancement of traits.

AIM OF THIS COURSE

The major emphasis in this course is to phenotype well characterized physiological processes/plant traits associated with plant growth, development and productivity, besides, comprehensive approach to precise imposition of various abiotic stresses and capture genetic variability in adaptive traits. The aim is to employ these techniques for crop improvement programs.

The course is organized as follows:

No.	Blocks	Units
1.	**Phenotyping Physiological Processes**	1. Concept of Phenotyping
		2. Phenotyping for Traits for Crop Establishment
		3. Concept and Approaches to Identify Genotypes with Superior Growth Rate
		4. Identifying Photo-insensitive Genotypes-options and Approaches
		5. Identifying Thermo-insensitive Genotypes-options and Approaches
		6. Yield Structure Analysis- Relevant Yield Attributes
		7. Source-sink Relationship- Assessment of Limitation
		8. Identify Genetic RESOURCES for Abiotic Stress

LEARNING OUTCOMES

After completion of this course students are expected to develop clear concept and insight into phenotyping technologies associated with plant growth, development and productivity.

BLOCK 1: PHENOTYPING PHYSIOLOGICAL PROCESSES

Unit 1: Concept of Phenotyping

- Phenotyping technologies are essential component for assessing plant responses, identify superior trait donors, mitigation responses, trait introgression and trait based breeding.

Unit 2: Phenotyping for Traits for Crop Establishment

- Seed viability, seed dormancy, seed hydration rates, seed density and weight
- Seedling vigour in normal and adverse conditions

Unit 3: Concept and Approaches to Identify Genotypes with Superior Growth Rate

- Phenotyping for leaf expansion, leaf area index, light interception and crop extinction coefficient
- Pigment quantification for nitrogen and chlorophyll status - SPAD, anthocyanin and flavonoids – Duolex
- Growth rates by non-invasive techniques like NDVI, Concept of Net assimilation rate and DM/LAD; surrogates for photosynthetic traits; stomatal characteristic

Unit 4: Identifying Photo-insensitive Genotypes-options and Approaches

- Exposing to longer and shorter photoperiod by staggered sowing; extending the day length- light interception by red light; days to heading/ anthesis, approaches for synchronization of flowering

Unit 5: Identifying Thermo-insensitive Genotypes-options and Approaches

- Altering total degree days- staggered sowing at lower latitudes or by growth chambers; quantifying heading, anthesis, maturity and grain filling days, grain number and weight, grain filling rate.

Unit 6: Yield Structure Analysis- Relevant Yield Attributes

- Pollen biology, stigma receptivity, spikelet sterility (cereals), floral abscission (other crops), fruiting points / productive tillers, number of grains/ fruits per panicle/ inflorescence and grain characteristic
- Phenotyping for lodging- culm traits, intermodal length, lignification, Phenylalanine ammonia lyase (PAL) and Tyrosine ammonia lyase(TAL)
- Approaches to identify genetic resources with traits to improve yield potential

Unit 7: Source-sink Relationship- Assessment of Limitation

- Phenotyping for source-sink size, Concept of sink-source limitation- defloration and defoliation
- Remobilization of stored metabolites and concept of stay green; estimation of water soluble carbohydrates;partitioning coefficient and harvest index.

Unit 8: Identify Genetic Resources for Abiotic Stress Constraints

- Approaches for precise stress imposition to diverse stresses
- Identify trait donor lines for different stresses: approaches by Stress Susceptibility Index (SSI), Stress Induction Response (SIR)
- Capturing variability for adaptive traits: root traits, stomatal factors/wax, osmolyte, surrogate approach for acquired tolerant traits, Flowering response, Spikelet fertility, Abscission and Senescence

- Screening high density response-based on SSI – root adaptation and Shade Avoidance Response (SAR)

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

Unit 1:

- Kumar, J., Pratap, A., and Kumar, S. 2015. Plant Phenomics: An Overview. 10.1007/978-81-322-2226-2_1.
- Pratap, A., Gupta, S., Nair, R. M., Gupta, S. K. Schafleitner, R.,Basu, P. S., Singh, C. M., Prajapati, U., Gupta, A. K., Nayyar, H., Mishra, A. K.,Baek, K.-H. 2019, Using Plant Phenomics to Exploit the Gains of Genomics. *Agronomy*, *9*, 126.

Unit 2:

- AOSA. 2009. Seed Vigor Testing Handbook. Contribution No. 32 to the Handbook on Seed Testing.
- Finch-Savage, W. E., andBassel, G. W. (2015). Seed vigour and crop establishment: extending performance beyond adaptation. *Journal of experimental botany*, *67*(3), 567-591.

Unit 3

- Muñoz-Huerta, R., Guevara-Gonzalez, R., Contreras-Medina, L., Torres-Pacheco, I., Prado-Olivarez, J., and Ocampo-Velazquez, R. (2013). A review of methods for sensing the nitrogen status in plants: advantages, disadvantages and recent advances. *sensors*, *13*(8), 10823-10843.
- Xue, J and Su, B., 2017, Significant Remote Sensing Vegetation Indices: A Review of Developments and Applications, Journal of Sensors, 2017: 17 https://doi.org/10.1155/2017/1353691.

Unit 4

- Ouzounis, T., Rosenqvist, E., and Ottosen, C., 2015, Spectral Effects of Artificial Light on Plant Physiology and Secondary Metabolism: A Review American society horticulture science. 50(8) 1128–1135 doi.org/10.21273/ HORTSCI.50.8.1128

Unit 5

- The Flowering Response of the Rice Plant to Photoperiod : A Review of The Literature Fourth Edition.

Unit 6:

Unit 7:

- White, A. C., Rogers, a., Rees, M and Osborne, C.P., 2016, How can we make plants grow faster? A source–sink perspective on growth rate Journal of Experimental Botany, 67(1): 31–45.

- Ragheba, A., El-Shimyb, H andRaghebb, G., (2016) Green architecture: a concept of sustainability, Procedia - Social and Behavioral Sciences 216: 778 – 787.

Unit 8:

- Wang, H., Wu, G., Zhao, B., Wang, B., Lang, Z., Zhang, C., and Wang, H.,2016, Regulatory modules controlling early shade avoidance response in maize seedlings, *BMC Genomics***17**:269, https://doi.org/10.1186/s12864-016-2593-6.
- Carriedo, L., Maloof, J and Brady, S., (2016). Molecular control of crop shade avoidance. Current Opinion in Plant Biology. 30. 151-158. 10.1016/j.pbi.2016.03.005

Credit: 2+0

Course Code: PP 512

Title: CROP GROWTH REGULATION AND MANAGEMENT

WHY THIS COURSE?

Besides crop improvement, the approach to regulate physiological processes for improving crop production made very good leads in recent years. The focus is to employ the basic knowledge of several physiological processes to manipulate the plant growth and specific processes like ripening, flowering to achieve higher economic yields. This dynamic course will address many of these technologies that are being developed for crop production based on principles of plant physiological processes. Training the students in this student ready coursewill provide the required practical knowledge which will be of immense relevance to contribute private agricultural sectors and for agri-based industries.

AIM OF THIS COURSE

A comprehensive information needs to be provided in this course like light regulation in polyhouse cultivation, photoperiod responses by red/far red light for synchronizing flowering, techniques for soil less culture like aeroponics, pollen biology and hybrid production, chemical regulation of plant growth processes like flower initiation, flower sex, flower drop, fruit maturity, ripening and shelf-life etc.

The course is organized as follows:

No	Blocks	Units
1	**Propagation - Crop Establishment**	1. Seed as a Propogule
		2. Vegetative Propogule
2	**Regulation of Plant Growth Processes**	1. Regulation of Plant Growth and Flowering
		2. Fruit Ripening and its Regulation
		3. Concept of Senescence and its Retardation
3	**Protective Cultivation – Stress Mitigation**	1. Protective Cultivation Interventions to Alter Physiological Processes and Growth
		2. Drought Mitigation Options and Approaches
		3. Specific Plant Processes Regulated by Chemicals and Growth Hormones

LEARNING OUTCOMES

BLOCK 1: PROPAGATION - CROP ESTABLISHMENT

Unit 1: Seed as a Propogule

- Concept of improving seed characteristics for crop establishment. Mechanisms of regulating seed dormancy, precocious germination, ways to control pre-harvest sprouting in crop plants
- Seed viability and its regulation, factors to minimize loss of viability and improve seedling vigour.
- Concept of seed priming, techniques of priming, seed priming to induce tolerance to stresses.
- Role of media, nutrition and PGPR's on seedling vigour and subsequent crop establishment

Unit 2:VegetativePropogule

- Chemical and hormonal regulation of vegetative propagation
- Regulation of rooting, bud sprouting, Bulb/tuber dormancy
- Chemical regulation of graft union.
- Concept of*invitro*micropropogation

BLOCK 2: REGULATION OF PLANT GROWTH PROCESSES

Unit 1: Regulation of Plant Growth and Flowering

- Chemical and hormonal regulation of plant architecture, tillering, branching, bud breaking
- Regulation of flowering by photo and thermoperiod, nutrients, chemicals and hormones, concept of speed breeding
- Flowering synchrony in hybrid seed production
- Sex ratio alteration, flower and fruit thinning
- Pollen viability in relation to environment, harvesting, storage and transportation
- Prevention of abscission, flower and fruit drop, seed and fruit growth regulation- role of hormones.

Unit 2: Fruit Ripening and its Regulation

- Approaches to improve shelf life – storage environment, water loss, respiration
- Modified atmosphere, gaseous environment for storage , storage disorders, chilling injury

Unit 3: Concept of Senescence and its Retardation

- Physiology of senescence and options to regulate.
- Chemical regulation of senescence, maintenance of chlorophyll during

storage, role of hormones/micronutrients in reducing senescence.

- Concept of stay green, advantages and limitations. Relevance of stay green traits in plant breeding for crop improvement.

BLOCK 3: PROTECTIVE CULTIVATION –STRESS MITIGATION

Unit 1: Protective Cultivation Interventions to Alter Physiological Processes and Growth

- Spectral characteristics of light in polyhouse, light regulation to optimize plant photosynthetic and photomorphogenic processes and plant growth
- LED sources of monochromatic light to regulate growth, etiolating and flowering
- High temperature induced thermomorphogenic processes
- Artificial growing media, soilless cultures, aeroponics, fogoponics
- Concept of CO2 fertilization. Effect of humidity on leaf expansion and growth.

Unit 2: Drought Mitigation Options and Approaches

- Moisture conservation options at soil and plant level
- Concept of increasing water holding capacity, role of Hydrogels – water and mineral nutrients release pattern.
- Approaches to improve transpiration over evapo-transpiration, stomatal and non-stomatal regulation of water loss, antitranspirants.
- Osmoprotectants, ROS scavengers, plant nutrients.
- Root stocks in improving tolerance
- Chemical regulation of flower drop due to temperature Chemicals to improve pollen viability during abiotic stress

Unit 3: Specific Plant Processes Regulated by Chemicals and Growth Hormones

- Rooting of cuttings
- Wine brewing industry
- Promotion of gynoecious flower
- Hybrid rice production
- Induction of flowering in pine apple, cucurbits
- Delaying of senescence and ripening
- Production of dwarf plant for ornamental purpose
- Reduction in flower and fruit drop
- Increase in berry size in grapes

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)

- Student presentation

RESOURCES

Block 1:

Unit 1:

- Wu X, Ning F, Hu X and Wang W(2017). Genetic Modification for Improving Seed VigorIsTransitioning from Model Plantsto Crop Plants. Front. Plant Sci. 8:8.doi: 10.3389/fpls.2017.00008
- William E. Finch-Savage and Steven Footitt. Seed dormancy cycling and the regulation of dormancy mechanisms to time germination in variable field environments ***Journal of Experimental Botany***, Volume 68, Issue 4, 1 February 2017, Pages 843 856,https://doi.org/10.1093/jxb/erw477
- Irfan Afzal, Hafeez Ur Rehman,MuhammadNaveed and ShahzadMaqsood Ahmed Basra Recent Advances in Seed Enhancements Intech 2016

Unit 2:

- Techniques and Experiments Plant Tissue Culture Techniques and Experiments Copyright © 2013 Elsevier Inc. All rights reserved 2013
- Amrit K. Nanda and Charles W. Melnyk. The role of plant hormones during grafting .jPlant Res. 2018; 131(1): 49–58.Published online 2017 Nov 27. doi: 10.1007/s10265- 017-0994-5PMCID: PMC5762790

Block 2:

Unit 1:

- Jorge J. Casa,andSureshkumarBalasubramanian. Thermomorphogenesis, Annual Review of Plant Biology, Vol. 70:321-346 (Volume publication date April 2019). First published as a Review in Advance on February 20, 2019 https://doi.org/10.1146/annurev-arplant-050718-095919
- Abraham H Halevy Handbook of Flowering: Volume V*CRC press, 2018*
- Amy Watson, Sreya Ghosh, Lee T. Hickey Speed breeding is a powerful tool to accelerate crop research and breeding. *Nature Plants*volume 4, pages23–29 (2018)

Unit 2:

- Kusumaningrum, D., Lee, S. H., Lee, W. H., Mo, C., and Cho, B. K. (2015). A review of technologies to prolong the shelf life of fresh tropical fruits in Southeast Asia. *Journal of Biosystems Engineering*, *40*(4), 345-358.
- Sandarani, MDJC, Dasanayaka DCMCK and Jayasinghe CVL (2018) Strategies Used to Prolong the Shelf Life of Fresh Commodities. J AgriSci Food Res 9: 206.
- Falagán, N and Terry, L. A. (2018). Recent advances in controlled and modified atmosphere of fresh produce. *Johnson Matthey Technology*

Review, *62*(1), 107-117.

Unit 3:

- Kim, J., Kim, J. H., Lyu, J. I., Woo, H. R., and Lim, P. O. (2017). New insights into the regulation of leaf senescence in Arabidopsis. *Journal of experimental botany*, *69*(4), 787-799.
- Luche, H. D. S., Silva, J. A. G. D., Maia, L. C. D., and Oliveira, A. C. D. (2015). Stay-green: a potentiality in plant breeding. *Ciência Rural*, *45*(10), 1755-1760.

Block 3:

Unit 1:

- Bian, Z., Jiang, N., Grundy, S. and Lu, C., 2017, August. Uncovering LED light effects on plant growth: new angles and perspectives-LED light for improving plant growth, nutrition and energy-use efficiency. In *International Symposium on New Technologies for Environment Control, Energy-Saving and Crop Production in Greenhouse and Plant 1227* (pp. 491-498).
- Barrett, G.E., Alexander, P.D., Robinson, J.S. and Bragg, N.C., 2016. Achieving environmentally sustainable growing media for soilless plant cultivation systems–A review. *Scientiahorticulturae*, *212*, pp.220-234.
- Raviv, M., Lieth, J.H. and Bar-Tal, A. eds., 2019. *Soilless Culture: Theory and Practice: Theory and Practice*. Elsevier.

Unit 2:

- Wang, P., Deng, Y., Li, X.Y., Wei, Z., Hu, X., Tian, F., Wu, X., Huang, Y., Ma, Y.J., Zhang, C. and Wang, Y., 2019. Dynamical effects of plastic mulch on evapotranspiration partitioning in a mulched agriculture ecosystem: Measurement with numerical modeling. *Agricultural and Forest Meteorology*, *268*, pp.98-108.
- GernotBodner, Alireza, Hans-Peter, Management of crop water under drought: A review. Agronomy for sustainable development. 2, 401-442

Course Title with Credit Load for Ph.D. in Plant Physiology

CODE	COURSE TITLE	CREDITS
PP 601*	FUNCTIONAL GENOMICS AND GENES ASSOCIATED WITH A FEW PHYSIOLOGICAL PROCESSES	2+0
PP 602*	SIGNAL PERCEPTIONS AND TRANSDUCTION AND REGULATION OF PHYSIOLOGICAL PROCESSES	2+0
PP 603*	MOLECULAR APPROACHES FOR IMPROVING PHYSIOLOGICAL MECHANISMS THROUGH TRAIT INTROGRESSION	2+1
PP 604	PLANT PHENOMICS – NEXT GENERATION PHENOMICS PLATFORMS	2+0
PP 605	EXPERIMENTAL TECHNIQUES TO CHARACTERIZE PLANT PROCESSES FOR CROP IMPROVEMENT	0+2
PP 606	GLOBAL CLIMATE CHANGE AND CROP RESPONSE	2+0
PP 607	PHYSIOLOGICAL AND MOLECULAR ASPECTS OF SOURCE-SINK CAPACITY FOR ENHANCING YIELD	3+0
PP 608	SEED AND FRUIT GROWTH AND THEIR QUALITY IMPROVEMENT	2+0
PP 609	PLANT-MICROBE INTERACTIONS	2+1
PP 610	WEED BIOLOGY AND PHYSIOLOGY OF HERBICIDE ACTION	2+0
PP 691	DOCTORAL SEMINAR I	1+0
PP 692	DOCTORAL SEMINAR II	1+0
PP 699	DOCTORAL RESEARCH	75

*Core courses

Credit : **2+0**
Course Code : **PP 601***
Title : **FUNCTIONAL GENOMICS AND GENES ASSOCIATED WITH A FEW PHYSIOLOGICAL PROCESSES**

WHY THIS COURSE?

Agriculture in India faces tremendous challenges on multiple fronts. There is a need for targeted improvement of crops to meet the increasing food demand. Thorough understanding of the plant physiological processes, pathways and genes associated with the pathways are needed for speed breeding and trait improvement. With help of modern tools and techniques, in the genomic ear, a large amount of data on genomic resources has been developed. The post-genomic era concentrates on assigning functions to the every gene identified in plants. The PhD scholar working on plant biology and related field must be exposed to recent trends and developments in this new emerging area. The major emphasis would be on new developments in genomics to regulate plant growth.

AIM OF THIS COURSE

The major goal is to expose the students of higher education program on functional genomic approaches, which is needed for crop improvement in a targeted way:

i) Identify genes regulating the specific mechanisms/traits

ii) Assess the relevance of physiological processes/mechanisms and options to combine / introgress them.

The course is organized as follows:

No.	Blocks	Units
1.	**Functional Genomics and Genes : Physiological Processes**	1. Gene Discovery
		2. Genetic Tools for Plant Development
		3. Gene Knock Out Approaches
		4. Chemical Genomics
		5. Gene Over Expression Approaches
		6. Synthetic Biology and Interaction Studies
		7. Case Studies

LEARNING OUTCOMES

After successful completion of this course students are expected to have in depth knowledge on the genetic tools for plant development

BLOCK 1: FUNCTIONAL GENOMICS AND GENES: PHYSIOLOGICAL PROCESSES

Unit 1: Gene Discovery

- Finding genes in complex plant system, Constructing gene-enriched plant genomic libraries
- Recent advancements in genome sequencing, RNA sequencing and expression.
- In Silico prediction of plant gene function, Quantitative Trait Locus analysis as a gene discovery tool
- Gene expression analysis –micro-array and deep sequencing, small RNA and Degradome,
- Study of methylome and its significance

Unit 2: Genetic Tools for Plant Development

- Understanding the importance of mutants in unrevealing the physiological processes, genome wide insertional mutagenesis – T-DNA insertion mutants, Gain in function, Transposon mutagens, Transposition.
- Physical and Chemical mutagenesis
- Gene and Enhancer Traps for Gene Discovery
- High-Throughput TAIL-PCR as a Tool to identify DNA Flanking insertions, High- Throughput TILLING for functional Genomics.
- Genome editing approaches for functional analysis of genes

Unit 3: Gene Knock Out Approaches

- PTGS-Antisense technology
- Virus induced gene silencing (VIGS)
- Custom Knock-outs with Haripin RNA-mediated Gene Silencing and other silencing tools
- Complementation studies

Unit 4: Chemical Genomics

- Reverse chemical genomic approaches for functional validation of genes.
- Protein structure prediction, homology modelling and virtual screening by using bioinformatic approaches to identify the small molecules and their validation through phenotyping assessment.

Unit 5: Gene Over Expression Approaches

- Vector Construction for Gene Overexpression as a Tool to Elucidate Gene Function
- Transient expression, Transgenics
- Targeted and conditional expression of transgene
- Multiple gene expression by Nanostring technology
- Co-expression analysis and gene networking to identify potential genes in the pathway (informatics)
- Epigenetics

Unit 6: Synthetic Biology and Interaction Studies

- Engineering microbial pathways in plants (eg, photosynthesis)
- DNA-protein & Protein-protein interaction studies, yeast hybrid system.
- Correlating the data from genome, transcriptome, proteome, metabolome and ionome with phenome
- Multivariate analysis and identification of metabolite as biomarkers

Unit 7: Case Studies

- Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling photosynthesis and nutrient uptake
- Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling respiration and photorespiration
- Functional characterization of genes associated with important cellular processes influencing crop growth and development: fatty acid biosynthesis, seed protein quality and quantity
- Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling flowering

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

Unit 1:

- Regulation of Gene Expression in Plants. J.A. Gatehouse, in Plant Biochemistry, 1997
- Plant genome sequencing, Delphine Fleury, ... Peter Langridge, in Plant Biotechnology and Agriculture, 2012
- Baxevanis, A. D. and Ouellette, B. F. F. (eds).. Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins, Methods of Biochemical Analysis, (2001) vol. 43, 2nd ed., New York: John Wiley and Sons, Inc.
- Gene Expression Analysis: Methods and Protocols, 2018 Editors: Raghavachari, Nalini, Garcia-Reyero, Natàlia (Eds.) , ISBN 978-1-4939-7834-2, Springer
- Transcriptome Data Analysis: Methods and Protocols, 2018 Editors: Wang, Yejun,

Sun, Ming-an (Eds.), 2018, ISBN 978-1-4939-7710-9; Springer

- Comparative Genomics: Methods and Protocols, 2018 Editors: Setubal, João C., Stoye, Jens, Stadler, Peter (Eds.) ISBN 978-1-4939-7463-4; Springer

Unit 2:

- Genetic Engineering Dr.Eugene Rosenberg, in It's in Your DNA, 2017
- Recombinant DNA Technology and Genetically Modified Organisms, Padma Nambisan, in An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology, 2017

Unit 3:

- A Versatile Vector Toolkit for Functional Analysis of Rice Genes, Feng He, Fan Zhang, Wenxian Sun, YueseNing,corresponding author and Guo-Liang Wang. Rice (N Y). 2018; 11: 27.doi: 10.1186/s12284-018-0220-7
- Genome Editing in Plants: An Overview of Tools and Applications, Venera S. Kamburova, Elena V. Nikitina, Shukhrat E. Shermatov, Zabardast T. Buriev, Siva P.
- Kumpatla, Chandrakanth Emani, and Ibrokhim Y. Abdurakhmonov, International Journal of Agronomy, 2017, https://doi.org/10.1155/2017/7315351
- Gene Silencing, Renu Bhardwaj, Ravinder Singh, in Emerging Technologies and Management of Crop Stress Tolerance, Volume 1, 2014

Unit 4:

- Chemical genomics approaches in plant biology. Norambuena L, Raikhel NV, Hicks GR. Methods Mol Biol. 2009;553:345-54. doi: 10.1007/978-1-60327-563-7_18.
- Plant Chemical Genetics: From Phenotype-Based Screens to Synthetic Biology. Wim Dejonghe and Eugenia Russinova, Plant Physiol. 2017 May; 174(1): 5–20.doi: 10.1104/pp.16.01805
- A plant-based chemical genomics screen for the identification of flowering inducers, MartijnFiers, JorinHoogenboom, Alice Brunazzi, Tom Wennekes, Gerco C. Angenent and Richard G. H. Immink, Plant Methods201713:78, https://doi.org/10.1186/s13007- 017-0230-2

Unit 5:

- Gene Overexpression RESOURCES in Cereals for Functional Genomics and Discovery of Useful Genes, Kiyomi Abe and Hiroaki Ichikawa, Front Plant Sci. 2016; 7: 1359. doi: 10.3389/fpls.2016.01359
- Gene Overexpression: Uses, Mechanisms, and Interpretation, Gregory Prelich, GENETICS March 1, 2012 vol. 190 no. 3 841-854; https://doi.org/10.1534/genetics.111.136911

Unit 6:

- Plant synthetic biology, Wusheng Liu C. Neal Stewart Jr https://doi.org/10.1016/j.tplants.2015.02.004 , REVIEW| 20, 5, P309-317, 2015

- Plant Synthetic Biology: Quantifying the "Known Unknowns" and Discovering the "Unknown Unknowns" R. Clay Wright, Jennifer Nemhauser, 2019. DOI: https://doi.org/10.1104/pp.18.01222
- Plant synthetic biology for molecular engineering of signalling and development, Jennifer L. Nemhauser and Keiko U. Torii, Nat Plants. 2016 Mar 2; 2: 16010.doi: 10.1038/nplants.2016.10

General Source Information

- Plant Biotechnology-the genetic manipulation of plants: A. Slater (2008) 2nd edition, Oxford University Press.
- Genetically Modified Crops (2011) 2nd edition, Imperial College Press, Worlds Scientific Publishers)
- Teaching Tools in Plant Biology, The American Society of Plant Biologists
- Lincoln Taiz and Eduardo Zeiger. Plant Physiology, 4 and 5th Edition.
- Methods in Biotechnology (2009) by John Walker
- Principles of Gene Manipulation and Genomics (2006) by Sandy B. Primrose and Richard Twyman
- Functional Genomics, Edited by GermanaMeroni, 2012
- Bioinformatics And Functional Genomics 3rd Edition, Wiley-Blackwell, 2009, http://pevsnerlab.kennedykrieger.org/php/?q=book3
- Functional Genomics, 2002, Editors: **Town**, Chris (Ed.), ISBN 978-94-010-0448-0, Springer
- Functional Genomics: Methods and Protocol, 2017, Editors: Kaufmann, Michael, Klinger, Claudia, Savelsbergh, Andreas (Eds.), ISBN 978-1-4939-7231-9 Springer
- Genomes 4 by T. A. Brown (Author) 2017, Taylor and Francis
- Genomics of Plant Genetic RESOURCES, ISBN: 9789400775749, 9400775741 Springer
- Plant Reverse Genetics, Editors: **Pereira**, Andy (Ed.), 2011, ISBN 978-1-60761-682-5
- Pevsner J. Bioinformatics and Functional Genomics, 3rd Edition, Wiley-Blackwell.
- Lesk AM. Introduction to Genomics, 3rd Edition, Oxford University Press.
- Neal Stewart C Jr. Plant Biotechnology and Genetics: Principles, Techniques, and Applications, 2nd Edition, Wiley.
- Grotewold E, Chappell J, Kellogg E. Plant Genes, Genomes and Genetics. Wiley.
- Buchanan BB, Gruissem W, Jones RL. Biochemistry and Molecular Biology of Plants. 2nd Edition. Wiley-Blackwell.
- Lesk A. Introduction to Bioinformatics, 4th Edition, Oxford University Press.

- Tramontano A, Lesk AM. Protein Structure Prediction: Concepts and Applications, Wiley

Credit : **2+0**

Course Code : **PP 602***

Title : **SIGNAL PERCEPTIONS AND TRANSDUCTION AND REGULATION OF PHYSIOLOGICAL PROCESSES**

WHY THIS COURSE?

Biosignaling is emerging as an import fields in plant biology. Thorough understanding of signal perception, activation and cellular changes associated is needed for manipulation of specific traits or events in plants. The M.Sc. PhD scholar working on plant biology and related field must be exposed to this new emerging area. Plant response to external and internal factors is mainly through signal perception and amplification leading gene expression which brings in altered metabolism regulating physiological and biochemical processes and finally plant processes and growth. The course provides insights on the diverse receptors, ligand receptor interaction and the role of secondary messengers in signal amplification leading to gene expression and finally regulating plant growth.

AIM OF THIS COURSE

Objective of this course is to provide comprehensive exposure on different signaling events and associated cellular changes in plants. The course will include lectures on the signalling mechanisms employed by plants to perceive and transduce environmental signals.

The course is organized as follows:

No	Blocks	Units
1	**Signal Perceptions and Transduction : Regulation of Physiological Processes**	1. Concept of Receptor and Ligands
		2. Receptors – Signal Perception and Transfer
		3. Hormone Signaling
		4. Light Signaling
		5. Abiotic Stress Signaling and Nutrient Signalling
		6. Signaling Cascade during Developmental Events
		7. Signal Perception and Transduction in Plant Defense Responses

LEARNING OUTCOMES

By the end of this course, the student will be able to:

1. comprehendvarioussignaling events and associated physiological changes in plants.

2. understand the diverse roles of receptors, ligand receptor interaction and the role of secondary messengers in signal amplification leading to gene expression.

BLOCK 1: SIGNAL PERCEPTIONS AND TRANSDUCTION : REGULATION OF PHYSIOLOGICAL PROCESSES

Unit 1: Concept of Receptor and Ligands

- Signal, signal types, long (diffusible) and short (contact) range signaling and components of signaling.
- Types of receptors, nature of ligands, downstream components like primary, secondary signaling components.

Unit 2: Receptors – Signal Perception and Transfer

- Cell surface trans-membrane receptors- GPCRs, Receptor Tyrosine Kinases (RTKs), Receptors Serine Threonine kinases (RSTKs), Receptor-Like Kinases (RLKs), receptor two component systems.
- Signal transfer phosphor-relay and generation of secondary signaling components and activation of TFs or enzymes.
- Downstream components- G-proteins, second messengers-Cyclic AMP, Adenylate cyclase cascade, cyclic GMP, calcium-calmodulin-kinases; effector molecules (transcription factor).

Unit 3: Hormone Signaling

- Hormone binding receptors-Transduction process. Effector molecules and gene expression.
- Specific signaling pathways of Auxins, Cytokinin, Gibberellins, Ethylene, ABA, Brassinosteroids, Salicylic Acid, Strigolactone, polyamines, Jasmonic acid, etc. which leads to formative effects.
- Cross talk in the signaling of different hormones-significance of studies with hormone action mutants.

Unit 4: Light Signaling

- Perception of light-pigments involved- activation of phytochrome/cryptochrome (study of mutants).
- Light signal transduction.
- Multiple signaling cascades-identification of signaling components through mutant analysis-changes in gene expression.

Unit 5: Abiotic Stress Signaling and Nutrient Signalling

- Sensing of environmental factors (Temperature-Osmotic-Ionic stress)
- Activation of specific molecules and secondary messengers, activation of downstream components-leading to stress gene expression.
- Case studies with different abiotic stresses.
- Retrograde signaling.
- Nitrogen fixation, nitrogen and phosphorus uptake, nutrient translocation.

Unit 6: Signaling Cascade during Developmental Events

- Leaf senescence/fruit development and ripening.

- Tuberization.
- Sugar signaling.
- Signaling during seed germination.

Unit 7: Signal Perception and Transduction in Plant Defense Responses

- General mechanisms to pathogen response.
- Role of salicylic acid and active oxygen species.
- Cross Talk Signaling- Stress matrix under field conditions, cross talk between abiotic- abiotic stress, biotic-abiotic stress signaling networks.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

Block 1:

Unit 1:

- He, Y., Zhou, J., Shan, L. and Meng, X., 2018. Plant cell surface receptor-mediated signaling–a common theme amid diversity. J Cell Sci, 131(2), p.jcs209353.
- Hall, M.A., Smith, A.R., Novikova, G.V. and Moshkov, I.E., 1999. Perception and transduction of ethylene. New Comprehensive Biochemistry, 33, pp.475-490.
- Huber, A.E. and Bauerle, T.L., 2016. Long-distance plant signaling pathways in response to multiple stressors: the gap in knowledge. Journal of Experimental Botany, 67(7), pp.2063-2079.
- Pollard, T.D., Earnshaw, W.C., Lippincott-Schwartz, J. and Johnson, G., 2016. Cell Biology E-Book. Elsevier Health Sciences.

Unit 2 :

- Braun, Y., Smirnova, A.V., Weingart, H., Schenk, A. and Ullrich, M.S., 2007. A temperature-sensing histidine kinase—function, genetics, and membrane topology. In Methods in enzymology (Vol. 423, pp. 222-249). Academic Press.
- Unden, G., Wörner, S. and Monzel, C., 2016. Cooperation of secondary transporters and sensor kinases in transmembrane signalling: the DctA/DcuS and DcuB/DcuS sensor complexes of Escherichia coli. In Advances in microbial physiology (Vol. 68, pp. 139-167). Academic Press.
- Ortiz-Urquiza, A. and Keyhani, N.O., 2016. Molecular genetics of Beauveria bassiana infection of insects. In Advances in genetics (Vol. 94, pp. 165-249). Academic Press.
- Snijders, L. and Naguib, M., 2017. Communication in animal social networks: a missing link. Adv Study Behav, 49, pp.297-359.

Unit 3:

- Hedden, P. and Thomas, S.G. eds., 2008. Annual Plant Reviews, Plant

Hormone Signaling (Vol. 24). John Wiley and Sons.

- Eckardt, N.A., 2015. The plant cell reviews dynamic aspects of plant hormone signaling and crosstalk.
- Chow, B. and McCourt, P., 2006. Plant hormone receptors: perception is everything. Genes and development, 20(15), pp.1998-2008.

Unit 4:

- Leduc, N., Roman, H., Barbier, F., Péron, T., Huché-Thélier, L., Lothier, J., Demotes- Mainard, S. and Sakr, S., 2014. Light signaling in bud outgrowth and branching in plants. Plants, 3(2), pp.223-250.
- Kami, C., Lorrain, S., Hornitschek, P. and Fankhauser, C., 2010. Light-regulated plant growth and development. In Current topics in developmental biology (Vol. 91, pp. 29- 66). Academic Press.
- Coureux, P.D. and Genick, U.K., 2007. Triggering and Monitoring Light-Sensing Reactions in Protein Crystals. In Methods in enzymology (Vol. 422, pp. 305-337). Academic Press.

Unit 5:

- Wang, C.S., Hsu, S.W. and Hsu, Y.F., 2013. New insights into desiccation-associated gene regulation by Lilium longiflorum ASR during pollen maturation and in transgenic Arabidopsis. In International review of cell and molecular biology (Vol. 301, pp. 37-94). Academic Press.
- Ben-Ari, G. and Lavi, U., 2012. Marker-assisted selection in plant breeding. In Plant Biotechnology and Agriculture (pp. 163-184). Academic Press.
- Peleg, Z.V.I., Walia, H. and Blumwald, E., 2012. Integrating genomics and genetics to accelerate development of drought and salinity tolerant crops. In Plant Biotechnology and Agriculture (pp. 271-286). Academic Press.
- Zhu, J.K., 2016. Abiotic stress signaling and responses in plants. Cell, 167(2), pp.313- 324.
- Pandey, G.K., Pandey, A., Prasad, M. and Böhmer, M., 2016. abiotic stress signaling in plants: functional genomic intervention. Frontiers in plant science, 7, p.681.
- Inaba, T., Yazu, F., Ito-Inaba, Y., Kakizaki, T. and Nakayama, K., 2011. Retrograde signaling pathway from plastid to nucleus. In International review of cell and molecular biology(Vol. 290, pp. 167-204). Academic Press.

Unit 6:

- Khan, M.I.R., Reddy, P.S., Ferrante, A. and Khan, N.A. eds., 2019. Plant Signaling Molecules: Role and Regulation Under Stressful Environments. Woodhead Publishing.
- Sparks, E., Wachsman, G. and Benfey, P.N., 2013. Spatiotemporal signalling in plant development. Nature Reviews Genetics, 14(9), p.631.
- Becraft, P.W., 2002. Receptor kinase signaling in plant development. Annual review of cell and developmental biology, 18(1), pp.163-192.
- Sparks, E., Wachsman, G. and Benfey, P.N., 2013. Spatiotemporal signalling in plant development. Nature Reviews Genetics, 14(9), p.631.

Unit 7:

- Rabellino, D., Boyd, J.E., McKinnon, M.C. and Lanius, R.A., 2019. The Innate Alarm System: A Translational Approach. In Stress: Physiology, Biochemistry, and Pathology (pp. 197-212). Academic Press.
- Newton, A.C., Torrance, L., Holden, N., Toth, I.K., Cooke, D.E., Blok, V. and Gilroy, E.M., 2012. Climate change and defense against pathogens in plants. In Advances in applied microbiology (Vol. 81, pp. 89-132). Academic Press.
- Reverchon, S., Muskhelisvili, G. and Nasser, W., 2016. Virulence program of a bacterial plant pathogen: the Dickeya model. In Progress in molecular biology and translational science (Vol. 142, pp. 51-92). Academic Press.
- Rabellino, D., Boyd, J.E., McKinnon, M.C. and Lanius, R.A., 2019. The Innate Alarm System: A Translational Approach. In Stress: Physiology, Biochemistry, and Pathology (pp. 197-212). Academic Press.
- Reverchon, S., Muskhelisvili, G. and Nasser, W., 2016. Virulence program of a bacterial plant pathogen: the Dickeya model. In Progress in molecular biology and translational science (Vol. 142, pp. 51-92). Academic Press.
- Davies, P.J. ed., 2004. Plant hormones: biosynthesis, signal transduction, action!. Springer Science and Business Media.
- Dzhavakhiya, V.G. and Shcherbakova, L.A., 2007. Creation of disease-resistant plants by gene engineering. In Comprehensive and Molecular Phytopathology (pp. 439-466). Elsevier.
- Dyakov, Y.T. and Ozeretskovskaya, O.L., 2007. Vertical pathosystem: avirulence genes and their products. In Comprehensive and Molecular Phytopathology (pp. 181- 215). Elsevier.
- Yamane, H., Konno, K., Sabelis, M., Takabayashi, J., Sassa, T. and Oikawa, H., 2010. Chemical defence and toxins of plants.
- Vinutha, T., Gupta, O.P., Prashat, G.R., Krishnan, V. and Sharma, P., 2014. Molecular mechanism of Begomovirus evolution and plant defense response. In Plant Virus–Host Interaction (pp. 345-357). Academic Press.

General Source Information

- Laszlo Bogre and Gerrit Beemster, 2008. Plant cell monographs. Plant Growth Signaling.
- Signals and Signal Transduction Pathways in Plants by Klaus Palme (Editor), 2012, Springer ISBN-13: 9789401041072
- Memon, A.R. and Durakovic, C., 2014. Signal perception and transduction in plants. Periodicals of Engineering and Natural Sciences (PEN), 2(2).
- Signal Transduction Mechanism: EduRev: https://edurev.in/studytube/Lecture-15- Signal-transduction-mechanisms/d82aff0d-53d8-4d71-a16c-185c6bdb517b_p
- Signaling and Communication in Plants, ISBN-10: 3540892273Springer; 2009 edition (March 18, 2009)
- Signal Transduction in Plants: Current Advances; 2012, by S K Sopory (Editor), Ralf Oelmuller (Editor), S C Maheswari (Editor), ISBN-13:

9781461355182

- Plant Signalling Networks: Methods and Protocols, by Dr.Zhi-Yong Wang, Springer, 2016, ISBN-13: 9781493961696
- Developmental and Cell Biology Series: Hormones, Signals and Target Cells in Plant Development Series Number 41, by Daphne J. Osborne, Michael T. McManus, Cambridge University Press, ISBN-13: 9780521330763
- How Plants Communicate by Sarah Machajewski, 2018, Rosen Education Service, ISBN-13:9781538301852
- Signal Transduction in Plants by P Aducci (Editor), 2011, ISBN-13:9783034899383
- Reactive Oxygen Species: Signaling Between Hierarchical Levels in Plants, by Franz- Josef Schmitt (Editor), Suleyman I Allakhverdiev (Editor), 2017, Wiley- ScrivenerISBN-13: 9781119184881
- Biocommunication: Sign-Mediated Interactions Between Cells and Organisms by Richard Gordon (Editor), Joseph Seckbach (Editor), 2017, World Scientific Publishing Europe Ltd ISBN-13: 9781786340443
- Annual Plant Reviews: Intracellular Signaling in Plants by Peter Hedden, Richard Napier, Zhenbiao Yang (Editor) 2008, Wiley-Blackwell (an imprint of John Wiley and Sons Ltd) ISBN-13: 9781405160025

Credit: 2+1

Course Code: PP 603*

Title: MOLECULAR APPROACHES FOR IMPROVING PHYSIOLOGICAL MECHANISMS THROUGH TRAIT INTROGRESSION

WHY THIS COURSE?

Phenomenal progress in understanding the basic physiological mechanisms that determine crop performance has been made in recent years. Extensive deciphering of the molecular and genetic basis of variations in these mechanisms has led to the enumeration of several “physiological traits” that have enormous relevance to improve yield potentials as well as adaptation to various biotic and abiotic stresses. Although most of the physiological traits have been considered as complex and hard to breed, recent advances in understanding the sub-components of most of the major mechanisms coupled with the progress made in “phenotyping” to capture genetic variability in such subcomponent traits have paved way for the adoption of “trait based breeding” approaches. The tremendous progresses made in genomics have also led to the development of extensive molecular and genetic resources that can be used for a focused “breeding by design”.

AIM OF THIS COURSE

Deep understanding of modern translational research methods such as molecular breeding, transgenics, genome editing, grafting and reverse breeding approaches such as Doubled haploidization will be provided to the students. Contemporary developments in molecular approaches in accelerated crop improvement would be dealt with. Acquainting with the approaches and techniques is crucial for young students to groom themselves into focused and successful scientists in future. Theoretical and practical concepts of trait introgression (or trait pyramiding) will be discussed in this course so as to provide recent developments in this area of research. To acquaint with regulatory aspects of working with transgenic plants is crucial and will be discussed elaborately.

The course is organized as follows:

No.	Blocks	Units
1.	**Trait Introgression through Molecular Breeding**	1. Physiological Traits Relevant for Crop Improvement and their Phenotyping
		2. Identification of QTL by Bi-parental Mapping Approach
		3. Identification of QTLs by Association Mapping Approach
		4. Trait Introgression by Molecular Breeding Approaches
2.	**Trait Introgression through Transgenic Technology**	1. Gene Discovery and Gene Constructs for Relevant Plant Traits/Adaptive Mechanisms
		2. Trait Improvement or Pyramiding through Transgenic Technology
		3. Genome Editing, a Potential Option for Gene Regulation by Transgenic Approach
		4. Characterization of Transformed Plants and E Selection Strategies
3.	**Other Approaches for Trait Introgression**	1. Trait Introgression through Tissue Grafting and Asexual Propagation
		2. Doubled haploids for Trait Introgression

LEARNING OUTCOMES

By the end of this course, the student will be able to:

1. comprehend the basic concepts of modern translational research methods such as molecular breeding, transgenics, genome editing, grafting etc.
2. describe reverse breeding approaches such as doubled haploidization
3. accumulate both theoretical and practical concepts of trait introgression

BLOCK 1: TRAIT INTROGRESSION THROUGH MOLECULAR BREEDING

Unit 1: Physiological Traits Relevant for Crop Improvement and their Phenotyping

- Physiological traits with relevance to growth, development, biotic/abiotic stress tolerance, nutrient acquisition
- Concept of complex, multi-gene control of physiological traits
- Concepts of trait introgression to augment crop productivity and/or stress adaptation.

Unit 2: Identification of QTL by Bi-parental Mapping Approach

- Concepts of developing trait-specific mapping population and identification of contrasting parental lines through phenotyping
- Mapping populations and their developments – F2, RIL, doubled haploid populations
- Accurate phenotyping of bi-parental mapping populations
- Conventional Genotyping strategies using SNP and SSR markers, other rapid approaches like GBS, RADseq, QTLseq etc.,
- Composite interval mapping and other approaches for QTL discovery

Unit 3: Identification of QTLs by Association Mapping Approach

- Concepts of assembling a "Panel" of germplasm amenable for association mapping based on molecular and phenotypic diversity.
- Concepts of linkage disequilibrium, LD decay and population structure
- Concepts QTL discovery in structured populations
- Phenotyping of the association mapping populations
- Concepts of Genome wide association studies (GWAS)

Unit 4: Trait Introgression by Molecular Breeding Approaches

- Strategies for QTL introgression and Marker Assisted Selection (MAS).
- Various breeding methods for trait introgression: Marker assisted backcross breeding (MABC),
- Marker assisted recurrent selection (MARS),
- Marker assisted phenotypic selection (MAPS) etc.

BLOCK 2: TRAIT INTROGRESSION THROUGH TRANSGENIC TECHNOLOGY

Unit 1: Gene Discovery and Gene Constructs for Relevant Plant Traits/Adaptive Mechanisms

- Map-based cloning to identify novel genes and their allelic variants
- Identification of differentially expressed genes through transcriptome, metabolome and proteome analysis in contrasting genotypes.
- Gene identification through forward (inducing mutations with radiation, chemicals, or insertional mutagenesis)and reverse genetic approaches (site-directed mutagenesis, gene knockout or knockdown)
- Cloning full-length candidate genes, inducible promoters
- Concepts of "codon optimization" to make constructs for specific crops

Unit 2: Trait Improvement or Pyramiding through Transgenic Technology

- Introduction to GMOs and its application in crop improvement
- Gene stacking strategies for trait improvement
- *Agrobacterium* and other methods of plant transformation including gene gun, *in planta,* etc

Unit 3: Genome Editing, a Potential Option for Gene Regulation by Transgenic Approach

- Genome editing techniques: CRISPR/Cas9, Zinc finger nucleases etc
- CRISPR as tool to generate loss-of-function and gain-of-function transgenics

Unit 4: Characterization of Transformed Plants and Event Selection Strategies

- Molecular analysis bySouthern, qRT-PCR/Northern analysis, and immunoassays
- Concepts of copy number and desirable number of independent events
- Evaluation of transgenics based on empirical/physiological/biochemical processes under specific conditions – containment and confined field trials
- Generation of T1 populations, event characterization
- Molecular data as per regulatory requirements
- Biosafety and Regulatory aspects of GMO

BLOCK 3: OTHER APPROACHES FOR TRAIT INTROGRESSION

Unit 1: Trait Introgression through Tissue Grafting and Asexual Propagation

- Concept of identifying root stocks with superior traits, grafting, scion root stock interaction, compatibility, concept of chimeric grafting in transgenic technology involving a non-transgenic shoot to a transgenic root.

Unit 2: Doubled haploids for Trait Introgression

- Concept of crossing trait donor lines and developing doubled haploids from the F1 anthers.
- Screening and identifying trait introgressed doubled haploids.

PRACTICALS

Phenotyping approaches for the different physiological traits. Development of SSR, SNP and SCAR markers, resolution of polymorphism on agarose gels and PAGE, genotyping options for SSR markers using capillary and chip based fragment analysis systems. scoring of gels and assessment of polymorphism Statistical approaches to assess genetic variability, heritability and other parameters. Phylogenetic analysis and principle component analysis and construction of dendrograms. Construction of Linkage map, QTL maps, population structure, LD decay etc leading to identification of QTLs.

Bioinformatics – sequence analysis, structure analysis, designing primers for SSR regions, SNP2CAPS approaches of genotyping. Molecular biology - genomic/plasmid DNA isolation, RNA isolation. Full-length gene cloning, vector construction with specific promoter, gene stacking and transient assays. Transformation in model system Crop transformation - *Agrobacterium* mediated transformation (in-planta and invitro), particle-gun transformation. Evaluation of transgenics – semiquantitative and quantitative RT-PCR, southern blot, northern blot, western blot and ELISA, biochemical/physiological assay based on the function of gene and testing

LOD. Improvement of traits based on grafting options. Techniques in developing doubled haploids and characterization.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

RESOURCES

Block 1:

Unit 1:

- Physiological breeding I: interdisciplinary approaches to improve crop adaptation Edited by Reynolds, M.P. 2012. Chapters 2, 3, 5: 153
- Reynolds M.and Langridge P., 2016, Physiological breeding. Current Opinion in Plant Biology, 31:162–17.1
- Sheshshayee M.S., Preethi N.V., Rohini S., Sowmya H.R., Smitharani A., Pooja B., PrathibhaM.D.and Raju Soolanayakanahally,2018, Introgression of Physiological Traits for a Comprehensive Improvement of Drought Adaptation in Crop Plants. Front. Chem., 10.
- Mariano Cossani and Reynolds M., 2012, Physiological Traits for Improving Heat Tolerance in Wheat. Plant Physiology, Vol. 160:1710–1718
- Thomas Payne, Matt hew Reynolds and Bent Skovmand, Searching genetic resources for useful variation in physiological traits Chapter 5. Physiological breeding I: interdisciplinary approaches to improve crop adaptation edited by Reynolds, M.P.

Unit 2:

- David Bonnett, Optimizing marker-assisted selection (MAS) strategies for crop improvement. Chapter 14: 153 Physiological breeding I: interdisciplinary approaches to improve crop adaptation edited by Reynolds, M.P.
- Breeding Rice for Drought-Prone Environments Edited by K.S. Fischer, R. Lafitte, S. Fukai, G. Atlin, and B. Hardy. 2003, IRRI. Section 4. What molecular tools are available for selection for drought tolerance?
- B.C.Y. Collard, M.Z.Z. Jahufer, J.B. Brouwer and E.C.K. Pang, An introduction to markers, quantitative trait loci (QTL) mapping and marker-assisted selection for crop improvement: The basic concepts.Euphytica(2005) 142: 169–196
- Alexander E Lipka, Catherine B Kandianis, Matthew E Hudson, Jianming Yu, Jenny Drnevich, Peter J Bradbury and Michael. A Gore From association to prediction: statistical methods for the dissection and selection of complex traits in plants. Current Opinion in Plant Biology 2015, 24:110–118
- Yang Xu, Pengcheng Li, Zefeng Yang, Chenwu Xu. Genetic mapping of quantitative trait loci in crops. The crop journal 5 (2017) 175–184
- Khanh Le Nguyen, Alexandre Grondin, Brigitte Courtois, and Pascal Gantet. Next- Generation Sequencing Accelerates Crop Gene Discovery. Trends in Plant Science, March 2019, Vol. 24, No. 3

Unit 3:

- Jesse A. Poland and Trevor W. Rife, Genotyping-by-Sequencing for Plant Breeding and Genetics. THE PLANT GENOME, 2012. 5:3
- Bertrand C. Y. Collard and David J. Mackill. Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. Phil. Trans. R. Soc. B (2008) 363, 557–572
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Unit 4:

- Bertrand C.Y Collard and David J Mackill. 2007. Marker-assisted selection: an approach for precision plant breeding in the twenty-first century**.** Phil Trans. Ser B2007
- Xu, Yunbi, and Jonathan H. Crouch. "Marker-assisted selection in plant breeding: from publications to practice." Crop science 48.2 (2008): 391-407.
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- Arya, K. V., and Shylaraj, K. S. (2019). Introgression of Sub1 QTL (Submergence tolerant QTL) into the elite rice variety Jaya by Marker Assisted Backcross Breeding. Journal of Tropical Agriculture, 56(2).
- Anyaoha, C. O., Fofana, M., Gracen, V., Tongoona, P., and Mande, S. (2019). Introgression of Two Drought QTLs into FUNAABOR-2 Early Generation Backcross Progenies Under Drought Stress at Reproductive Stage. Rice Science, 26(1), 32-41.

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Block 2:

Unit 1:

- Visarada, K. B. R. S., Kanti Meena, C. Aruna, S. Srujana, N. Saikishore, and N. Seetharama. "Transgenic breeding: perspectives and prospects." Crop Science 49, no. 5 (2009): 1555-1563.
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- Ramalingam, Abirami, HimabinduKudapa, Lekha T. Pazhamala, Wolfram Weckwerth, and Rajeev K. Varshney. "Proteomics and metabolomics: two emerging areas for legume improvement." Frontiers in plant science 6 (2015): 1116.
- Jankowicz-Cieslak, Joanna, and Bradley J. Till. "Forward and reverse genetics in crop breeding." In Advances in plant breeding strategies: breeding, biotechnology and molecular tools, pp. 215-240. Springer, Cham, 2015.
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Unit 2:

- Kamthan, Ayushi, Abira Chaudhuri, Mohan Kamthan, and Asis Datta. "Genetically modified (GM) crops: milestones and new advances in crop improvement." Theoretical and applied genetics 129, no. 9 (2016): 1639-1655.
- Chen, Weiqiang, and David W. Ow. "Precise, flexible and affordable gene stacking for crop improvement." Bioengineered 8, no. 5 (2017): 451-456.
- Joung, Young Hee, Pil-Son Choi, Suk-Yoon Kwon, and Chee Hark Harn. "Plant Transformation Methods and Applications." In Current Technologies in Plant Molecular Breeding, pp. 297-343. Springer, Dordrecht, 2015.

Unit 3:

- Gaj, Thomas, Charles A. Gersbach, and Carlos F. Barbas III. "ZFN, TALEN, and CRISPR/Cas-based methods for genome engineering." Trends in biotechnology 31, no. 7 (2013): 397-405.

Unit 4:

- Register III, James C. "Approaches to evaluating the transgenic status of transformed plants." Trends in biotechnology 15, no. 4 (1997): 141-146.
- Prabhu, K. V. "Use of GMOs Under Containment, Confined and Limited Field Trials and Post-Release Monitoring of GMOs." Biosafety of Genetically Modified Organisms: Basic concepts, methods and issues (Chowdhury MKA, Hoque MI, Sonnino A, eds). Food and Agriculture Organization of the United Nations, Rome (2009): 157-220.
- Chen, Wei, and PoHao Wang. "Molecular Analysis for Characterizing Transgenic Events." In Transgenic Plants, pp. 397-410. Humana Press, New York, NY, 2019.
- Giller, K. E. Genetically Engineered Crops: Experiences and Prospects. National Academies of Sciences, Engineering, and Medicine, 2016.

Block 3:

Unit 1:

- Wu, Rui, Xiaoran Wang, Yan Lin, Yiqiao Ma, Gang Liu, Xiaoming Yu, Silin Zhong, and Bao Liu. "Inter-species grafting caused extensive and heritable alterations of DNA methylation in Solanaceae plants." PLoS One 8, no. 4 (2013): e61995.

Unit 2:

- Doubled Haploid Production in Crop Plants. Editors: W. T. B. Thomas B. P. Forster B. Gertsson. Page 337-349, 2003
- Forster, B. P., and Thomas, W. T. (2005). Doubled haploids in genetics and plant breeding. Plant Breed Rev, 25, 57-88.

Credit: 2+0

Course Code: PP 604

Title: PLANT PHENOMICS-NEXT GENERATION PHENOMICS PLATFORMS

WHY THIS COURSE?

Crop improvement in the present scenario is increasing focusing on trait based breeding. The phenomenal progress made in genomics cannot be exploited for improving plant traits/mechanisms unless phenotyping technologies are developed to capture genetic variability. Several technologies have been developed to accurately quantify genetic variability in specific traits.

AIM OF THIS COURSE

The course aims at providing cutting edge knowledge on the current progress made in various phenotyping techniques and approaches. The students will be versed with principles of various phenotyping approaches. The aim is to provide hands-on expertise in analyzing trait diversity. Exposure will be provided on Non-invasive imaging technologies that drive the phenomics platforms. The course provides comprehensive exposure on recent developments in phenomics platforms imaging tools/techniques and recent trends in designing specific phenomics platforms e.g. drought studies/root phenotyping etc.

The course is organized as follows:

No	Blocks	Units
1	**Concepts of High throughput Phenotyping and its Requirement**	1. Concepts of Phenotyping
		2. Physio-Morphological Traits Associated with Crop Performance
		3. Features of Phenomic Platforms
		4. Trends in Phenomics
		5. Non-invasive Phenotyping Approaches
2	**Applications of the Phenomics Platforms**	1. Basic Studies to Assess the Crop Response
		2. Applied Studies Focused on Crop Improvement Programs

LEARNING OUTCOMES

By the end of this course, the student will be able to understand the current progress made in various phenotyping techniques and approaches.

BLOCK 1: CONCEPTS OF HIGH THROUGHPUT PHENOTYPING AND ITS REQUIREMENT

Unit 1: Concepts of Phenotyping

- The concepts of “phene and trait” analogous to gene and allele. Genome-phenome relationship, definition of phenotyping, GxE interaction on phenome.

Unit 2: Physio-Morphological Traits Associated with Crop Performance

- Overview of phenotyping needs to complement genomic resources, specific traits associated with yield potential, stress adaptation (both biotic and abiotic stresses).
- Need for high throughput precision phenotyping approaches for basic studies and to generate genetic and genomic resources.

Unit 3: Features of Phenomic Platforms

- Precision growth conditions, maintenance of light, temperature/VPD and RH to realize the potential crop growth response.
- Controlled environmental facilities for simulating challenging climatic conditions to phenotype diverse plant traits.
- Concept of sensors, diverse sensors and their utility in precise quantification of environmental variables, soil moisture sensors.
- Imaging to capture plant traits, image acquisition. Automated big data access, processing etc.

Unit 4: Trends in Phenomics

- Types of phenomic platforms- Laboratory, Greenhouse and the field-based platforms.

- Platforms designed for specific needs i.e., root phenotyping, drought studies etc., Crop specific phenotyping, mobile and stationary platforms.
- Global trends in establishing major phenomics platforms, and their characteristic features and impact.

Unit 5: Non-invasive Phenotyping Approaches

- **The concept of non-invasive capturing of plant growth and health**
  - Imaging technologies - image acquisition, segmentation and data analysis.
  - Critical aspects of Visual, IR Thermal, Fluorescence, NIR, Hyperspectral imaging.
  - Development and validation of models for deriving relevant physiological traits from image phenome.
- **Concepts of Plants to sensors and sensors to plants.**
  - Stationary and ground based tractor mounted sensors/imaging tools.
  - Unmanned aerial vehicle (UAV) sensors.
  - Machine learning and its integration to analyze ground and aerial based images.

BLOCK 2: APPLICATIONS OF THE PHENOMICS PLATFORMS

Unit 1: Basic Studies to Assess the Crop Response

- Functional validation of genes, chemicals and other interventions.
- Characterize the growth and stress response in contrasts to identify the relevance of adaptive trait

Unit 2: Applied Studies Focused on Crop Improvement Programs

Unit 1: Basic Studies to Assess the Crop Response

- Functional validation of genes, chemicals and other interventions.
- Characterize the growth and stress response in contrasts to identify the relevance of adaptive trait

Unit 2: Applied Studies Focused on Crop Improvement Programs

- Characterizing the pre-released promising lines for productivity under defined environmental variables. Phenotyping germplasm accessions, mapping populations for specific traits for mapping.
- Concept of Phenome Wide Association Studies (PWAS).
- Genomic selection, gene-based crop models to predict complex traits.
- Impact of phenomics platform, progress made, case studies.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

Block 1:

Unit 1:

- Pieruschka, R., and Poorter, H. (2012). Phenotyping plants: genes, phenes and machines. Functional Plant Biology, 39(11), 813-820.
- Fahlgren, Noah, Malia A. Gehan, and Ivan Baxter. "Lights, camera, action:

high- throughput plant phenotyping is ready for a close-up." Current opinion in plant biology 24 (2015): 93-99.

- Singh, A. K., Ganapathysubramanian, B., Sarkar, S., and Singh, A. (2018). Deep learning for plant stress phenotyping: trends and future perspectives. Trends in plant science.
- Lobos, G. A., Camargo, A. V., del Pozo, A., Araus, J. L., Ortiz, R., and Doonan, J. H. (2017). Plant phenotyping and phenomics for plant breeding. Frontiers in plant science, 8, 2181.
- Walter, A., Liebisch, F., and Hund, A. (2015). Plant phenotyping: from bean weighing to image analysis. Plant methods, 11(1), 14.

Unit 2:

- Rahnama, A., Munns, R., Poustini, K., and Watt, M. (2011). A screening method to identify genetic variation in root growth response to a salinity gradient. Journal of experimental botany, 62(1), 69-77.
- Okono, R. (2010). Practical measurement of generic drought adaptation-related traits. Drought phenotyping in crops: From theory to practice. Generation Challenge Programme, Cornell, USA, 451-457.
- Chen, D., Neumann, K., Friedel, S., Kilian, B., Chen, M., Altmann, T., and Klukas, C. (2014). Dissecting the phenotypic components of crop plant growth and drought responses based on high-throughput image analysis. The Plant Cell, 26(12), 4636- 4655.
- Lyu, J. I., Baek, S. H., Jung, S., Chu, H., Nam, H. G., Kim, J., and Lim, P. O. (2017). High-throughput and computational study of leaf senescence through a phenomic approach. Frontiers in plant science, 8, 250
- Jeudy, C., Adrian, M., Baussard, C., Bernard, C., Bernaud, E., Bourion, V. and Lamboeuf, M. (2016). RhizoTubes as a new tool for high throughput imaging of plant root development and architecture: test, comparison with pot grown plants and validation. Plant Methods, 12(1), 31.
- Großkinsky, D. K., Svensgaard, J., Christensen, S., and Roitsch, T. (2015). Plant phenomics and the need for physiological phenotyping across scales to narrow the genotype-to-phenotype knowledge gap. Journal of experimental botany, 66(18), 5429- 5440.

Unit 3:

- Ubbens, J. R., and Stavness, I. (2017). Deep plant phenomics: a deep learning platform for complex plant phenotyping tasks. Frontiers in plant science, 8, 1190.
- Tardieu, F., Cabrera-Bosquet, L., Pridmore, T., and Bennett, M. (2017). Plant phenomics, from sensors to knowledge. Current Biology, 27(15), R770-R783.
- Rahaman, M., Chen, D., Gillani, Z., Klukas, C., and Chen, M. (2015). Advanced phenotyping and phenotype data analysis for the study of plant growth and development. Frontiers in plant science, 6, 619.

Unit 4:

- Kumar, J., Pratap, A., and Kumar, S. (Eds.). (2015). Phenomics in crop plants: trends, options and limitations (No. 8, p. 296). New Delhi: Springer India.
- Costa, C., Schurr, U., Loreto, F., Menesatti, P., and Carpentier, S. (2018).

Plant phenotyping research trends, a science mapping approach. Frontiers in plant science, 9.

Unit 5:

- Das Choudhury, S., Samal, A., and Awada, T. (2019). Leveraging Image Analysis for High-Throughput Plant Phenotyping. Frontiers in Plant Science, 10, 508.
- Golzarian, M. R., Frick, R. A., Rajendran, K., Berger, B., Roy, S., Tester, M., and Lun, D. S. (2011). Accurate inference of shoot biomass from high-throughput images of cereal plants. Plant methods, 7(1), 2.
- JPPC - the Jülich Plant Phenotyping Centrehttps://www.fz-juelich.de/ibg/ibg- 2/EN/methods_jppc/methods_node.html
- Hartmann, A., Czauderna, T., Hoffmann, R., Stein, N., and Schreiber, F. (2011). HTPheno: an image analysis pipeline for high-throughput plant phenotyping. BMC bioinformatics, 12(1), 148.
- Berger, B., Parent, B., and Tester, M. (2010). High-throughput shoot imaging to study drought responses. Journal of experimental botany, 61(13), 3519-3528.
- Grift, T. E., Novais, J., and Bohn, M. (2011). High-throughput phenotyping technology for maize roots. Biosystems Engineering, 110(1), 40-48.
- Ge, Y., Bai, G., Stoerger, V., and Schnable, J. C. (2016). Temporal dynamics of maize plant growth, water use, and leaf water content using automated high throughput RGB and hyperspectral imaging. Computers and Electronics in Agriculture, 127, 625-632.,
- DominguesFranceschini, M., Bartholomeus, H., van Apeldoorn, D., Suomalainen, J., and Kooistra, L. (2017). Intercomparison of unmanned aerial vehicle and ground- based narrow band spectrometers applied to crop trait monitoring in organic potato production. Sensors, 17(6), 1428.
- Busemeyer, L., Mentrup, D., Möller, K., Wunder, E., Alheit, K., Hahn, V., and Rahe,

  F. (2013). BreedVision—A multi-sensor platform for non-destructive field-based phenotyping in plant breeding. Sensors, 13(3), 2830-2847.
- Li, L., Zhang, Q., and Huang, D. (2014). A review of imaging techniques for plant phenotyping. Sensors, 14(11), 20078-20111.

Block 2:

Unit 1:

- Banan, D., Paul, R., Feldman, M. J., Holmes, M., Schlake, H., Baxter, I., and Leakey,

  A. D. (2017). High fidelity detection of crop biomass QTL from low-cost imaging in the field. bioRxiv, 150144.
- Honsdorf, N., March, T. J., Berger, B., Tester, M., and Pillen, K. (2014). High- throughput phenotyping to detect drought tolerance QTL in wild barley introgression lines. PLoS One, 9(5), e97047.
- Rungrat, T., Awlia, M., Brown, T., Cheng, R., Sirault, X., Fajkus, J. .and Pogson, B.

  J. (2016). Using phenomic analysis of photosynthetic function for abiotic stress response gene discovery. The Arabidopsis Book/American Society of Plant Biologists, 14.

- Tanger, P., Klassen, S., Mojica, J. P., Lovell, J. T., Moyers, B. T., Baraoidan, M., and Leung, H. (2017). Field-based high throughput phenotyping rapidly identifies genomic regions controlling yield components in rice. Scientific Reports, 7, 42839.
- Zhang, X., Huang, C., Wu, D., Qiao, F., Li, W., Duan, L. and Xiong, L. (2017). High- throughput phenotyping and QTL mapping reveals the genetic architecture of maize plant growth. Plant physiology, 173(3), 1554-1564.
- Campbell, M. T., Knecht, A. C., Berger, B., Brien, C. J., Wang, D., and Walia, H. (2015). Integrating image-based phenomics and association analysis to dissect the genetic architecture of temporal salinity responses in rice. Plant physiology, 168(4), 1476-1489.
- Chen, D., Neumann, K., Friedel, S., Kilian, B., Chen, M., Altmann, T., and Klukas, C. (2014). Dissecting the phenotypic components of crop plant growth and drought responses based on high-throughput image analysis. The Plant Cell, 26(12), 4636- 4655.
- Parent, B., Shahinnia, F., Maphosa, L., Berger, B., Rabie, H., Chalmers, K., and Fleury, D. (2015). Combining field performance with controlled environment plant imaging to identify the genetic control of growth and transpiration underlying yield response to water-deficit stress in wheat. Journal of Experimental Botany, 66(18), 5481-5492.

Unit 2:

- Araus, J. L., and Cairns, J. E. (2014). Field high-throughput phenotyping: the new crop breeding frontier. Trends in plant science, 19(1), 52-61.
- Brown, T. B., Cheng, R., Sirault, X. R., Rungrat, T., Murray, K. D., Trtilek, M. and Borevitz, J. O. (2014). TraitCapture: genomic and environment modelling of plant phenomic data. Current opinion in plant biology, 18, 73-79.
- Pratap, A., Gupta, S., Nair, R. M., Gupta, S. K., Schafleitner, R., Basu, P. S. and Mishra, A. K. (2019). Using Plant Phenomics to Exploit the Gains of Genomics. Agronomy, 9(3), 126.Rahaman, M., Chen, D., Gillani, Z., Klukas, C., and Chen, M. (2015). Advanced phenotyping and phenotype data analysis for the study of plant growth and development. Frontiers in plant science, 6, 619.
- Campbell, Z. C., Acosta-Gamboa, L. M., Nepal, N., and Lorence, A. (2018). Engineering plants for tomorrow: how high-throughput phenotyping is contributing to the development of better crops. Phytochemistry Reviews, 17(6), 1329-1343.
- Araus, J. L., Kefauver, S. C., Zaman-Allah, M., Olsen, M. S., and Cairns, J. E. (2018). Translating high-throughput phenotyping into genetic gain. Trends in plant science, 23(5), 451-466.

General Source Information

- Montes, J. M., Melchinger, A. E., and Reif, J. C. (2007). Novel throughput phenotyping platforms in plant genetic studies. Trends in plant science, 12(10), 433- 436.
- Development of high throughput plant phenotyping facilities at aberystwyth (ppt)
- Zhou, J., Reynolds, D., Websdale, D., Le Cornu, T., Gonzalez-Navarro, O., Lister, C. and Clark, M. (2017). CropQuant: An automated and scalable field

phenotyping platform for crop monitoring and trait measurements to facilitate breeding and digital agriculture. BioRxiv, 161547.

- Bradshaw, J. E. (2017). Plant breeding: past, present and future. Euphytica, 213(3), 60.
- Lee, U., Chang, S., Putra, G. A., Kim, H., and Kim, D. H. (2018). An automated, high-throughput plant phenotyping system using machine learning-based plant segmentation and image analysis. PloS one, 13(4), e0196615.
- Furbank, R. T., and Tester, M. (2011). Phenomics–technologies to relieve the phenotyping bottleneck. Trends in plant science, 16(12), 635-644.

Credit: 0+2

Course Code: PP 605

Title: EXPERIMENTAL TECHNIQUES TO CHARACTERIZE PLANT PROCESSES FOR CROP IMPROVEMENT

WHY THIS COURSE?

Techniques, tools and instrumentation facilities drive the research in modern biology. The course addresses recent developments related to advanced quantification methods based on novel methodologies and instruments. Besides the emphasis is on new emerging trends in assessing physiological and biochemical processes based on surrogate methods. Several molecular biology techniques are now essential to comprehend physiological processes. The course provide comprehensive picture on these areas addressing recent developments in this area.

AIM OF THIS COURSE

Aim of this course is to provide exposure to phenotype very specific physiological processes which have direct relevance in crop improvement programmes. The course provides insight on recent techniques and methodologies on each of the major physiological processes like stress responses, photosynthetic process, hormone area, photo-morphogenesis and genomics aspects.

The course is organized as follows:

No.	Blocks	Units
1.	**Characterization of Plant Processes : Experimental Techniques and Crop Improvement**	1. Stress Responses
		2. Photosynthetic processes
		3. Hormonal Response on Specific Plant Growth Processes and Quantification
		4. Nutrient Response Acquisition and Quantification
		5. Photo and Thermo Morphogenesis
		6. Recent Approaches for Functional Genomics

LEARNING OUTCOMES

After completion of this course students are expected to develop practical skill and knowledge on various experimental techniques employed in crop improvement programme. Moreover, students will have experience with characterization of plant processes.

BLOCK 1: CHARACTERIZATION OF PLANT PROCESSES: EXPERIMENTAL TECHNIQUES AND CROP IMPROVEMENT

Unit 1:Stress Responses

- Thermal (reflectance) characters as a measure of water status and root characteristics.
- Oxidative stress induction and assessing the response on lipid peroxidation and quantification of ROS, RCC's, RNS
- Fluorescence to assess the stress response.
- Water use efficiency quantification at leaf, plant level, surrogates for WUE
- Tissue localization of ROS, RNS by qualitative staining and fluorescence-based methods

Unit 2:Photosynthetic processes

- Concept and approaches to assess of radiation utilization efficiency (RUE)
- Quantification of mesophyll and other diffusive resistances regulating photosynthesis
- Carboxylation efficiency (light and CO2 response curves)
- RuBiSCO activation status

Unit 3:Hormonal Response on Specific Plant Growth Processes and Quantification

- Bioassays to assess the biological process regulated by hormones – new in-vivo assays
- Promoter assays for hormone response- GUS/YFP/GFP based assays- expression of hormone responsive genes
- Recent analytical tools and techniques to quantify hormones – GC-MS, LC-MS, Capillary electrophoresis

Unit 4: Nutrient Response Acquisition and Quantification

- Recent advances in soil less cultures to study the nutrient response- Hydroponics/Aeroponics/Fogoponics.
- Noninvasive techniques to quantify nutrients – XRD (X-Ray Diffraction analysis) and hyper spectral reflectance.

Unit 5: Photo and Thermo Morphogenesis

- Photo receptors, light and temperature regulation of plant growth and flowering.
- Thermal time, heat units, GDD.
- Concept and approaches for speed breeding.

Unit 6:Recent Approaches for Functional Genomics

- In silico prediction of gene function.
- Flanking sequence identification in insertional (T-DNA/transposon) mutants.
- Concept of insertional mutagenesis and mutant experiments
- Utilization of genetic resources for functional genomics – mutants and tilling, eco tilling
- VIGS, RNAi, miRNA
- Genome editing –CRISPR
- Concept of chemical genomics for functional validation
- Relevant molecular tools to assess gene expression or (to regulate the process and assign a function to gene).
- Multiple gene expression by Nano String technology
- Cap analysis gene expression (CAGE) – to identify start point of transcription
- Yeast hybrid interaction.
- Immunoprecipitation
- Chip-PCR.

TEACHING METHODS / ACTIVITIES

- Practical Assignments
- Results presentation

RESOURCES

Unit 1:

- Costa, Miguel and Grant, Olga and Chaves, M. (2013). Thermography to explore plant-environment interactions. Journal of experimental botany. 64. 10.1093/jxb/ert029.
- Padhi, Jyotiprakash and K Misra, R and Payero, Jose. (2009). Use of infrared thermography to detect water deficit response in an irrigated cotton crop.
- Root Phenotyping for Drought Tolerance: A Review, Allah Wasaya, Xiying Zhang, Qin Fang and Zongzheng Yan, Agronomy 2018, 8, 241; doi:10.3390/agronomy8110241
- Zhang, Yinfeng, Menghong Dai, and Zonghui Yuan. "Methods for the detection of reactive oxygen species." Analytical Methods 10, no. 38 (2018): 4625-4638.
- Maxwell, Kate, and Giles N. Johnson. "Chlorophyll fluorescence—a practical guide." Journal of experimental botany 51, no. 345 (2000): 659-668.

Unit 2:

- Sinclair, Thomas R., and Russell C. Muchow. "Radiation use efficiency." In Advances in agronomy, vol. 65, pp. 215-265. Academic Press, 1999.

Unit 3:

- Yopp, John H., Louis Htin Aung, and George L. Steffens, eds. "Bioassays and other special techniques for plant hormones and plant growth regulators." Plant Growth Regulator Society of America, 1986.
- DeBlasio, Stacy L., Anne W. Sylvester, and David Jackson. "Illuminating plant biology: using fluorescent proteins for high-throughput analysis of protein localization and function in plants." Briefings in functional genomics 9, no. 2 (2010): 129-138.
- Ljung K., Sandberg G., Moritz T. (2010) Methods of Plant Hormone Analysis. In: Davies P.J. (eds) Plant Hormones. Springer, Dordrecht
- Šimura, Jan, IoannaAntoniadi, JitkaŠiroká, DanušeTarkowská, Miroslav Strnad, Karin Ljung, and OndřejNovák. "Plant hormonomics: Multiple phytohormone profiling by targeted metabolomics." Plant physiology 177, no. 2 (2018): 476-489.

Unit 4:

- Jones Jr, J. Benton. Hydroponics: a practical guide for the soilless grower. CRC press, 2016.
- Nir, I. "Growing plants in aeroponics growth system." In Symposium on Substrates in Horticulture other than Soils In Situ 126, pp. 435-448. 1981.
- Watson, Michael C. "Fogponic plant growth system." U.S. Patent Application 15/974,356 filed December 27, 2018.
- van Maarschalkerweerd, Marie, and Søren Husted. "Recent developments in fast spectroscopy for plant mineral analysis." Frontiers in plant science 6 (2015): 169.
- Fang, Qian, Hanlie Hong, Lulu Zhao, Stephanie Kukolich, Ke Yin, and Chaowen Wang. "Visible and near-infrared reflectance spectroscopy for investigating soil mineralogy: a review." Journal of Spectroscopy 2018 (2018).

Unit 5:

- Moe, Roar, and Royal D. Heins. "Thermo-and photomorphogenesis in plants." Advances in floriculture research. Report 6 (2000): 52-64.
- Watson, Amy, Sreya Ghosh, Matthew J. Williams, William S. Cuddy, James Simmonds, María-Dolores Rey, M. Asyraf Md Hatta *et al*. "Speed breeding is a powerful tool to accelerate crop research and breeding." Nature plants 4, no. 1 (2018): 23.

Unit 6:

- Kahl, Günter, and Khalid Meksem, eds. The handbook of plant functional genomics: concepts and protocols. John Wiley and Sons, 2008.

- Editors: Alonso, Jose M., Stepanova, Anna N. (Eds.) Plant Functional Genomics, Methods and Protocols 2015
- Dario Leister 1st Edition Plant Functional Genomics 2004
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Credit: 2+0

Course Code: PP 606

Title: GLOBAL CLIMATE CHANGE AND CROP RESPONSE

WHY THIS COURSE?

Present Indian agriculture encounters tremendous challenges due to rapid climate change. Climate change exerts remarkable negative impact on food, nutritional and ecological security. It significantly affects the plant physiological processes, hence yield is severely affected. Therefore students of plant physiology need to quip themselves with knowledge and skill sets required to navigate the climate change scenario and its impact on crops physiological processes. Hence, this course is designed .

AIM OF THIS COURSE

The course is designed to provide basic knowledge on the subjects of crop responses to climate change. The aim of this course is to address both long-term and short-term effects of climate change on crops, natural vegetations and ecosystems.

The course is organized as follows:

No.	Blocks	Units
1.	**Climate Change : Crop Response and Mitigation**	1. Fundamentals of Climate Change
		2. Manifestations of Climate Change
		3. Major GHGs (CO2, Methane, NO2 etc.), their Production Rates, Monitoring and their Influence on Climate Change
		4. Agricultural Practices on GHG Production
		5. Direct and Indirect Effects of Climate Change on Plant Processes
		6. Climate Change Scenario and Impact on Crops
		7. Ozone Depletion leading to Increased Ionizing Radiations and its Implications on Crop Growth
		8. Long-term and Short-term Projections of Climate Change : Effects on Natural Vegetation and Ecosystems
		9. Technologies for Climate Change Mitigation in Agriculture
		10. Climate-resilient Agriculture
		11. Climate Change: Technologies for Crop Response Studies
		12. Politics of Climate Change Negotiations

LEARNING OUTCOMES

After completion this course, students will be able to obtain in depth and basis knowledge on crop responses to climate change.

BLOCK 1: CLIMATE CHANGE : CROP RESPONSE AND MITIGATION

Unit 1: Fundamentals of Climate Change

Definition of climate change, history and evidences of climate change and its implications. Natural and anthropogenic climate change. Sources of Greenhouse Gas (GHG) emission, Global Warming Potential of GHGs, accumulation of

GHGs in the atmosphere and science behind climate change, industrial revolution and GHG build-up in the atmosphere, Energy- Emission-Economy Interactions, carbon intensity of economy, carbon equity/justice.

Unit 2: Manifestations of Climate Change

Impact on monsoons, occurrence of extreme weather events, hydrological cycle and water availability, effect on crop growing period in tropics, subtropics and temperate regions, shifts in distribution of flora and fauna, effects on biodiversity and migration of tropical plant species to higher latitudes and altitudes.

Unit 3: Major GHGs (CO2, Methane, NO2 etc.), their Production Rates, Monitoring and their Influence on Climate Change

GHGs: An Overview, - role of CO2, methane and major uncertainties. Mechanism of their production and emission from various, source and sinks of GHGs; and contribution of GHGs to global warming. Techniques used in monitoring GHGs.

Unit 4: Agricultural Practices on GHG Production

Carbon footprint analysis of agriculture and various agricultural practices contribute to climate change. Impacts of natural factors and farming practices on greenhouse gas emissions. Sources of agricultural GHG emission-Agricultural Soil Management, enteric fermentation, manure management, other sources. Opportunities to reduce GHG emission from Agriculture.

Unit 5: Direct and Indirect Effects of Climate Change on Plant Processes

Problems and Prospects of Crops with changing temperature: Growth and Development of Crop plants, Thermo-morphogenesis, phenology, Physiological processes such as photosynthesis, Net carbon assimilation, C3 and C4 plants adaptation,Respiration, Nutrient acquisition and metabolisms, Plant water relations and Heat shock proteins, Grain/seed development: Grain Quality parameters and yield.

Unit 6: Climate Change Scenario and Impact on Crops

Different scenarios for temperature, rainfall in different agro-climatic zones of India and their impact on crop growth and productivity. Major climate change (temperature, CO2, and rainfall) impact quantification using field or controlled environment experiments, meta- analysis and simulation models. Some examples of crop simulation models calibration and their application in short-term and long-term predictions.

Unit 7: Ozone Depletion leading to Increased Ionizing Radiations and its Implications on Crop Growth

Role of CFCs in ozone depletion, penetration of ionizing UV radiations and its implications on crop growth.

Unit 8: Long-term and Short-term Projections of Climate Change : Effects on

Natural Vegetation and Ecosystems

Response of natural ecosystems to increasingatmospheric CO_2 concentration and climate warming, effect of climate change on quality of feed i.e leaf and stored grains/seeds, its implications on pollinators and pests

Unit 9: Technologies for Climate Change Mitigation in Agriculture

a. Agricultural biotechnology to produce crop varieties with enhanced carbon uptake.
b. Nutrient management: Management of nitrogenous fertilizers;
c. Tillage/residue management: 1.Conservation tillage CO_2 mitigation technology; 2. Biochar: A potentialtechnique for carbon sequestration.
d. Methane mitigation using reduced tillage technology, change in methanogenic bacterial activity using electron acceptors.
e. Carbon sequestration potential, concept and measurement.

Unit 10: Climate-resilient Agriculture

Conventional and biotechnological approaches to improve the crop adaptation to climate change. Relevance of "Genome wide mutants" to identify genes/processes for improved adaptation to changing environments.

Unit 11: Climate Change: Technologies for Crop response studies

T emperature Gradient Chambers, Temperature Gradient Greenhouses, Soil plant atmosphere research system (SPAR), Infra-red warming Technology, Free Air temperature enrichment technology, Soil Warming system etc.

Unit 12: Politics of Climate Change Negotiations

IPCC, Major International conventions/treaties, Kyoto Protocol, Paris Agreement, Global initiatives on Carbon sequestration, carbon trading.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

- IPCC AR5 Reports WG I 2013
- IPCC AR5 Reports WG II and III 2014
- IPCC Special Reports
- UNFCCC website
- IPCC website
- NOAA website
- CCAFS website
- India’s Second National Communication to UNFCCC

- INCCA Report, MoEF and CC
- MoEF and CC website
- Research papers, review articles, National and International Reports
- Uprety, D.C. and Reddy,V.R.(2016), Crop responses to Global warming, Springer publication,ISBN 978-981-10-2004-9,pp 1-125 (2016)
- Climate Change and Agriculture Worldwide (Editor : Emmanuel Torquebiau) Springer Netherlands, 2015
- Climate Smart Agriculture: Building Resilience to Climate Change. Edited by Leslie Lipper, Nancy McCarthy, David Zilberman, Solomon Asfaw, GiacomoBranca, Springer, FAO, 2018
- Handbook of Climate Change and Agroecosystems:The Agricultural Model Intercomparison and Improvement Project (AgMIP) in 2 parts Kindle Editionby Rosenzweig Cynthia and Hillel Daniel (Author), Cynthia Rosenzweig (Editor), 2015
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temperature and socioeconomic changes. Scientific reports, 7(1), p.7800.

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Credit: 3+0

Course Code: PP 607*

Title: PHYSIOLOGICAL AND MOLECULAR ASPECTS OF SOURCE- SINK CAPACITY FOR ENHANCING YIELD

WHY THIS COURSE?

Yield level reached plateau in many crops improving yield potential and crop growth rate forms the basis for further improvement in productivity. Photosynthesis and the establishing sink capacity are crucial processes to achieve this goal. Very good progress has been made in deciphering the molecular mechanisms to regulate several photosynthetic processes at cellular and canopy level. Similar insights now exist regarding establishing sink size (capacity). In the last five years, phenomenal conceptual approaches have been developed to understand the basic physiological and molecular mechanisms to enhance the source through photosynthetic processes. Besides, scientific insights in recent years provided leads in improving sink ie., yield associated traits. Yield plateau can be broken only by enhancing yield potential by structured improvement in source capacity and sink size.

AIM OF THIS COURSE

The course addresses the recent development in photosynthetic processes that can be exploited to improve yield potential. Besides, other major emphasis is to provide exposure on recent developments in regulating the sink characters ie., yield attributes at molecular level to achieve higher potential yields

The course is organized as follows:

No.	Blocks	Units
1.	Source Size and Function- Basic Concepts, Physiological and Molecular Mechanisms, Genomic RESOURCES to Regulate Source Characters	1. Source Establishment
		2. Source Function- Photochemical Reactions
		3. Source Function- CO2 Diffusion and Concentration
		4. Source Function- Metabolic Engineering of CO2 Fixation
		5. Case Studies to Improve Source Capacity
2.	Improving Sink Size and Capacity	1. Sink Establishment
		2. Increase the Sink Size by Enhancing the Relevant Constituent Traits
		3. Genetic Genomic RESOURCES, Genes/QTLs, Genetic RESOURCES to Improve Sink Traits- Case Studies
		4. Source to Support the Sink Capacity

LEARNING OUTCOMES

By the end of this course, the student will be able to:

1. comprehend the current development in photosynthetic research
2. know how to employ the theoretical concept of photosynthetic research in yield improvement programme
3. understand the mechanisms of source and sink establishment

BLOCK 1: SOURCE SIZE AND FUNCTION- BASIC CONCEPTS, PHYSIOLOGICAL AND MOLECULAR MECHANISMS, GENOMIC RESOURCES TO REGULATE SOURCE CHARACTERS

Unit 1: Source Establishment

- Maximize energy capture by improved light interception, light distribution and its utilization efficiency, concepts of shade avoidance response (SAR) and option to increase.
- Increase canopy size by vertical expansion – concept of increasing optimum LAI levels.
- Concepts of semi-tall varieties with resistance to lodging: traits associated with

lodging resistance.

- Sustain net carbon gain with age – the relevance of stay green character, photon capture and achieve high CO_2 reduction to photon ratio under low light.
- Options for increasing canopy photosynthesis.
- Relevance of maintaining cell turgor and nutrient status.

Unit 2: Source Function- Photochemical Reactions

- Maximize conversion efficiency of intercepted radiation by improving net carbon gain - Emerging solutions to increase carbon fixation rate.
- Improve efficiency of photochemical reaction by - Engineering the pigments to expand PAR spectrum into IR range; reduce antenna size, optimize energy dissipation mechanisms; optimize components of ETC and downstream acceptors; accelerate adaptation for shifting light intensities.

Unit 3: Source Function- CO2 Diffusion and Concentration

- Enhance stomatal conductance (gs) and mesophyll conductance (gm) – guard cell metabolism; concepts of leaf mesophyll tissue thickness (SLW).
- Concepts of VPD responses of gs to enhance duration of photosynthesis during the day.
- Bicarbonate transports and aquaporins; achieve higher CCM - Engineering C4 cycle, CAM, cyanobacteria, carboxysomes, algal pyrenoids.

Unit 4: Source Function- Metabolic Engineering of CO2 Fixation

- RuBisCO carbon fixation activity - Increase and optimize kinetics of RuBisCO with enhanced specificity to CO_2.
- Engineer RuBisCO to minimize feedback regulation by metabolite inhibitors.
- Increased activation state by improving stability and function of RuBisCOactivase; optimize RuBp regeneration – modulate specific enzyme levels.
- New concepts on photorespiratory synthetic bypass.

Unit 5: Case Studies to Improve Source Capacity

- Genetic and genomic resources, genes/QTLs associated with specific yield potential traits and/or photosynthetic mechanisms.
- Genetic resources to improve source traits- case studies.

BLOCK 2: IMPROVING SINK SIZE AND CAPACITY

Unit 1: **Sink Establishment**

- Optimise duration of phenological stages related to sink establishment, genetic and environmental factors, GDD and phenology.

Unit 2: Increase the Sink Size by Enhancing the Relevant Constituent Traits

- Role of hormones in regulating molecular mechanisms of yield structure development.

- Genomic and genetic resources developed for regulation/improvement of such traits.
    - Sink Size: Tillering associated traits, branching patterns/fruiting points, spikelet number, pod number, fruit number.
    - Sink development: Basic concepts and molecular mechanisms associated with pollination, fertilization, ovary development in determining the spikelet fertility/sterility components and strategies for engineering seed/fruit size in crop plants.

Unit 3: Genetic and Genomic Resources, Genes/QTLs, Genetic Resources to Improve Sink Traits- Case Studies

- Progress and status in developing genomic and genetic resources of validated genes/QTLs to improve sink traits- Specific case studies.

Unit 4: Source to Support the Sink Capacity

- Canopy architecture to support sink requirements in cereals: plant height, tillering, leaf area, shading or senescence of lower canopy leaves, canopy photosynthesis.
- Canopy architecture to support sink requirements in Pulses: Leaf senescence, abscission, mobilization of N and other nutrients.
- Symbiotic N fixation to support sink size and capacity in pulses.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

Introduction –suggested reading

- Ray DK, Mueller ND, West PC, Foley JA (2013) Yield Trends Are Insufficient to Double Global Crop Production by 2050. PLoS ONE 8(6): e66428. doi:10.1371/journal.pone.0066428
- World Agricultural Supply and Demand Estimates (USDA), 2019
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Source establishment - suggested reading

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- Ricardo J. Haroa, Jorge Baldessaria, María E. Otegui (2017). Genetic improvement of peanut in Argentina between 1948 and 2004:Light interception, biomass production and radiation use efficiency. Field Crops Research 204, 222–228
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- Zhu X, Chen J, Qiu K and Kuai B (2017) Phytohormone and Light Regulation of Chlorophyll Degradation. Front. Plant Sci. 8:1911. doi: 10.3389/fpls.2017.01911
- Tomoaki Sato, YousukeShimoda, Kaori Matsuda, Ayumi Tanaka, Hisashi Ito (2018). Mg-dechelation of chlorophyll a by Stay-Green activates chlorophyll b degradation through expressing Non-Yellow Coloring in Arabidopsis thaliana. Journal of Plant Physiology 222 (2018) 94–102
- Mandy Christophera,∗, KarineChenub, RaeleenJenningsa, Susan Fletchera, David Butlera, Andrew Borrellc, Jack Christopher. (2018). QTL for stay-green traits in wheat in well-watered and water-limited environments. Field Crops Research 217 (2018) 32–44
- Howard Thomas and Helen Ougham (2014). The stay-green trait. Journal of Experimental Botany, Vol. 65, No. 14, pp. 3889–3900, 2014
- Makoto Kusaba • Ayumi Tanaka • Ryouichi Tanaka. Stay-green plants: what do they tell us about the molecular mechanism of leaf senescence. Photosynth Res DOI 10.1007/s11120-013-9862-x

Source function - suggested reading

- Qingfeng Song, Yu Wang, Mingnan Qu, Donald R. Ort, Xin-Guang Zhu. (2017). The impact of modifying photosystem antenna size on canopy photosynthetic efficiency— Development of a new canopy photosynthesis model scaling from metabolism to canopy level processes. Plant cell and environ. 40:2946–2957.
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- Benedict M. Long , Wei YihHee, Robert E. Sharwood, Benjamin D. Rae, Sarah Kaines*et al.*, Carboxysome encapsulation of the CO2-fixing enzyme Rubisco in tobacco chloroplasts. Nature communication DOI: 10.1038/s41467-018-06044-0
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- Brendon Conlan, Rosemary Birch, Celine Kelso, Sophie Holland1, Amanda P. De Souza, Stephen P Long, Jennifer L. Beck, Spencer M. Whitney. BSD is a Rubisco specific assembly chaperone, forms intermediary hetero-oligomeric complexes and is non-limiting to growth in tobacco.(2018) Plant physiol (accepted).
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- Frank A. Skraly, Madana M.R. Ambavaram, Oliver Peoples, Kristi D. Snell (2018). Metabolic engineering to increase crop yield: From concept to execution. Plant Science 273 (2018) 23–32.

Improving Sink source and its capacity -Suggested reading

- Paul, 2018, Are GM Crops for Yield and Resilience Possible? –Review, Trends in Plant Science, Jan; 23(1):10-16. doi: 10.1016/j.tplants.2017.09.007
- Ansari *et al*., 2019, Comparative Studies of Late Planted Capsicum (Capsicum annum) for Growth and Yield under Polyhouse and Open Field Condition as Influenced by Different Growth Regulators,Indian Res. J. Ext. Edu. Vol, 1, No. 1
- Khumsupan*et al*., 2019, CRISPR/Cas in Arabidopsis: overcoming challenges to accelerate improvements in crop photosynthetic efficiencies, PhysiologiaPlantarum.
- Amthor*et al*., 2019,Engineering Strategies to Boost Crop Productivity by Cutting 4 Respiratory Carbon Loss – Review, Plant Cell Advance Publication, doi:10.1105/tpc.18.00743
- Abdelrahman *et al*., 2018, Genome editing using CRISPR/Cas9–targeted mutagenesis: An opportunity for yield improvements of crop plants grown under environmental stresses Neglected pollinators,Plant Physiology and Biochemistry 131 (2018) 31–36
- Xu *et al*., 2018, Genome-Wide Association Analysis of Grain Yield-Associated Traits in a Pan-European Barley Cultivar Collection, Plant genome, 11(1). doi: 10.3835/plantgenome2017.08.0073.
- Sgarma*et al*., Genome-wide association of yield traits in a nested association mapping population of barley reveals new gene diversity for future breeding, Journal of Experimental Botany, Vol. 69, No. 16 pp. 3811–3822, 2018.
- Hong *et al*., Genome-wide identification and extensive analysis of rice-endosperm preferred genes using reference expression database, J. Plant Biol. (2017) 60:249-258.
- Mir *et al*., High-throughput phenotyping for crop improvement in the genomics era, Plant Science, In press
- Nadolska-Orezyk*et al*., Major genes determining yield-related traits in wheat and barley, TheorAppl Genet (2017) 130:1081-1098.
- Savadi, Molecular regulation of seed development and strategies for engineering seed size in crop plants- Review, Plant Growth Regulation (2018) 84:401–422
- Sonnewald*et al*., Next-generation strategies for understanding and influencing source–sink relations in crop plants, Current Opinion in Plant Biology 2018, 43:63–70
- Zhang *et al*., OsSRT1 is involved in rice seed development through regulation of starch metabolism gene expression, Plant Science 248 (2016) 28–36
- Scheben*et al*., Progress in single-access information systems for wheat and rice crop improvement, Briefings in Bioinformatics, 2018, 1–7
- Verma *et al*., Rice research to break yield barriers, Cosmos, Vol. 11, No. 1 (2015) 1– 18
- Li *et al*., Systems model-guided rice yield improvements based on genes controlling source, sink, and flow, 2018, Journal of Integrative Plant Biology, Volume 60, Issue 12, 1154–1180

- Temperature regulation of plant phenological development, Environmental and Experimental Botany, 2015, Volume 111, Pages 83-90.
- Paul *et al*., The Role of Trehalose 6-Phosphate in Crop Yield and Resilience, Plant Physiology_, May 2018, Vol. 177, pp. 12–23.
- Narnoliya*et al*., Transcriptional Signatures Modulating SAM Morphometric and Plant Architectural Traits Enhance Yield and Productivity in Chickpea, The plant journal, accepted paper

Course Code: PP 608 Credit: 2+0

Title: SEED AND FRUIT GROWTH AND THEIR QUALITY IMPROVEMENT

WHY THIS COURSE?

Seed as a propagule is an important input for agriculture. From this context, aspects related to seed development, its dormancy and viability etc. assumes significance. Besides, seed is the major source of nutrition to mankind and hence, quantitative and qualitative differences in seed constituents and their modification and improvement have been the area of focus in recent years. Several molecular approaches are now being adapted to improve the seed characters like longevity, vigour and seed quality. In addition to seed and fruit development, processes regulating the post-harvest deterioration of fruits and vegetables, increasing their self-life are another area that needs comprehensive intervention involving molecular biology tools and techniques. The course therefore addresses recent developments on these aspects.

AIM OF THIS COURSE

The major aim of the course is to train and educate the students about the importance of seeds and fruits as a source of nutrition for human health. Further, this course also addresses how to improve the nutritional status besides protecting the nutritive value of seeds and fruits. In addition, the other aim of the course is to address to regulate the post harvest deterioration of seeds and fruits to minimize the losses.

The course is organized as follows:

No.	Blocks	Units
1.	**Physiological and Molecular Aspects of Seed and Fruit Growth : Quality Improvement**	1. Physiology of Seed Growth and Development
		2. Seed as a Propagule
		3. Seed as a Source of Nutrition
		4. Quality Deterioration during Storage
		5. Fruit Growth and Development
		6. Fruit as a Source of Phytochemicals : Nutraceuticals
		7. Fruit Ripening, Post Harvest Deterioration and Shelf life

LEARNING OUTCOMES

After successful completion of this course, the students are expected to be able to:

1. comprehend the importance of seeds and fruits as a source of nutrition
2. describe how to improve the nutritional status of grains and fruits
3. know how to protect the nutritive value of seeds and fruits
4. detect the post harvest deterioration of seeds and fruits and to minimize the losses

BLOCK 1: PHYSIOLOGICAL AND MOLECULAR ASPECTS OF SEED AND FRUIT GROWTH: QUALITY IMPROVEMENT

Unit 1: Physiology of Seed Growth and Development

- Mechanism of seed development and different developmental stages; synthesis, mobilization and accumulation of stored reserves;
- Forms of stored reserves and their localization
- Sink drawing ability (SDA) and its relevance in seed growth and development;
- Role of plant hormones in seed growth and development and SDA

Unit 2: Seed as a Propagule

- Seed as a propagation material; seed size and seed chemical composition and their relevance in seed germination
- Physiological, biochemical and molecular mechanisms and approaches to regulate seed germination, seedling emergence and establishment and seedling vigour
- Physiological, biochemical and molecular mechanisms and approaches to regulate seed priming and crop establishment: seed dormancy, precocious germination and controlling pre-harvest sprouting in crops
- Physiological, biochemical and molecular mechanisms and approaches to regulate seed viability, improving the viability and storability of seeds

Unit 3: Seed as a Source of Nutrition

- Seed as a source of nutrition to humans: approaches to improve the quality of seeds through synthesis of seed storage reserves and other constituents.
- Genes/QTL's regulating these processes and concept of pathway engineering to improve the quantity and quality of seed constituents.
- Carbohydrates- Amylose and amylopectin ratios for glycemic index, resistant and digestable starch, improving dietary fibre, alter gelatinisation.
- Protein content, modified proteins, essential amino acids.
- Oil content, fatty acid composition, Omega 3 fatty acids. Carotenoids and vitamins
- Biofortification strategies to enhance the grain zinc, iron, other minerals and other essential compounds.
- Engineering for low protease inhibitors, phytic acid, tannins, phenolic

substances, lectins, oxalates as anti-nutritional factors.

- Case studies of improving seed nutrition components by molecular breeding and transgenic approaches.

Unit 4: Quality Deterioration during Storage

- Changes in chemical composition during storage; factors influencing the deterioration of nutritional quality of seeds during storage; approaches to minimize nutritional quality deterioration
- Effect of quality deterioration on human and animal health

Unit 5: Fruit Growth and Development

- Flower and fruit development; concept of parthenocarpy
- Physiological and biochemical changes during fruit development and chemical composition
- Molecular approaches to regulate flower and fruit drop/ abscission; Role of hormones

Unit 6: Fruit as a Source of Phytochemicals : Nutraceuticals

- Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Antioxidants, Flavanoids, anthocyanins
- Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Vitamins-Vitamin C, Tocopherol, Carotenoids
- Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Alkaloids, Mangiferin, tomatins
- Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of DigestableFiber lycopene, stillbeans
- Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Aroma, monoterpenoids and Fatty acid esters.

Unit 7: Fruit Ripening, Post Harvest Deterioration and Shelf life

- Physiological and molecular mechanisms of fruit ripening.
- Postharvest deterioration of fruits; factors regulating fruit deterioration; hormonal and environmental aspects of reducing post harvest deterioration of fruits
- Physiological and Molecular approaches to regulate fruit ripening and shelf life: Role of Ethylene and Ethylene response factors regulating specific processes of fruit ripening; Approaches to regulate specific shelf life characters.
- Improving fruit ripening and shelf life by molecular approaches-Case studies.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

Unit 1 &2:

- Bewley, JD, Bradford K,,Hilhorst H, Nonogaki H. (2013). Seeds: Physiology of Development, Germination and Dormancy, Springer-Verlag
- Larkins BA and Vasil IK (Ed), Cellular and Molecular Biology of Plant Seed Development, 2010, Springer
- Vanangamudi K, Natarajan K and Vanangamudi M, Seed Physiology, Associated Publishing Company
- N.W. Pammenter and Patricia Berjak (2000). Aspects of recalcitrant seed physiology. R.Bras. Fisiol. Veg., 12: 56-69.
- Prakash. M. 2011. Seed physiology of crops.(ed). Satish Serial Publishing house, New Delhi..

Unit 3:

- Lee, K.R., Chen, G.Q. and Kim, H.U., 2015. Current progress towards the metabolic engineering of plant seed oil for hydroxy fatty acids production. Plant cell reports, 34(4), pp.603-615.
- Zhu, Y., Xie, L., Chen, G.Q., Lee, M.Y., Loque, D. and Scheller, H.V., 2018. A transgene design for enhancing oil content in Arabidopsis and Camelina seeds. Biotechnology for biofuels, 11(1), p.46.
- Patil, G., Mian, R., Vuong, T., Pantalone, V., Song, Q., Chen, P., Shannon, G.J., Carter, T.C. and Nguyen, H.T., 2017. Molecular mapping and genomics of soybean seed protein: a review and perspective for the future. Theoretical and Applied Genetics, 130(10), pp.1975-1991.
- Tien Lea, D., Duc Chua, H. and Quynh Lea, N., 2016. Improving nutritional quality of plant proteins through genetic engineering. Current genomics, 17(3), pp.220-229.
- Ufaz, S. and Galili, G., 2008. Improving the content of essential amino acids in crop plants: goals and
- Mene-Saffrane, L. and Pellaud, S., 2017. Current strategies for vitamin E biofortification of crops. Current opinion in biotechnology, 44, pp.189-197.
- Jiang, L., Wang, W., Lian, T. and Zhang, C., 2017. Manipulation of metabolic pathways to develop vitamin-enriched crops for human health. Frontiers in plant science, 8, p.937.
- Abhishek Bohra, Uday Chand Jha, Rintu Jha, S. J. Satheesh Naik, Alok Kumar Maurya, and Prakash G. Patil, Chapter-1. Genomic Interventions for Biofortifcation of Food Crops, A. M. I. Qureshi *et al*. (eds.), Quality Breeding in Field Crops, https://doi.org/10.1007/978-3-030-04609-5_1
- Julia L Finkelstein, Jere D Haas and Saurabh Mehta, Iron-biofortified staple

food crops for improving iron status: a review of the current evidence, Current Opinion in Biotechnology 2017, 44:138–145

- Raul Antonio Sperotto, Felipe Klein Ricachenevsky, Vinicius de Abreu Waldow, Janette Palma Fett, Iron biofortification in rice: It's a long way to the top, Plant Science 190 (2012) 24–39
- Biofortification of Cereal Grains with Zinc by Applying Zinc Fertilizers, ForsideBioZoom 2009.
- Jeongyeo Lee, IllSupNou, HyeRan Kim, Current status in calcium biofortification of crops, J Plant Biotechnol (2012) 39:23–32, DOI:http://dx.doi.org/10.5010/JPB.2012.39.1.023
- Divya Sharma, Gautam Jamr,, Uma M. Singh, SalejSood and Anil Kuma, Calcium Biofortification: Three Pronged Molecular Approaches for Dissecting Complex Trait of Calcium Nutrition in Finger Millet (Eleusine coracana) for Devising Strategies of Enrichment of Food Crops,2017, doi: 10.3389/fpls.2016.02028
- Gemede, H.F. and Ratta, N., 2014. Antinutritional factors in plant foods: Potential health benefits and adverse effects. International Journal of Nutrition and Food Sciences, 3(4), pp.284-289.
- Vasconcelos, I.M. and Oliveira, J.T.A., 2004. Antinutritional properties of plant lectins. Toxicon, 44(4), pp.385-403.

Unit 4:

- Kumar, D. and Kalita, P., 2017. Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. Foods, 6(1), p.8.
- Kawakatsu, T., Hirose, S., Yasuda, H. and Takaiwa, F., 2010. Reducing rice seed storage protein accumulation leads to changes in nutrient quality and storage organelle formation. Plant Physiology, 154(4), pp.1842-1854.
- Afzal, I., Rehman, H.U., Naveed, M. and Basra, S.M.A., 2016. Recent advances in seed enhancements. In New Challenges in Seed Biology-Basic and Translational Research Driving Seed Technology. IntechOpen.
- Probert, R., Adams, J., Coneybeer, J., Crawford, A. and Hay, F., 2007. Seed quality for conservation is critically affected by pre-storage factors. Australian Journal of Botany, 55(3), pp.326-335.

Unit 5:

- Glenda Gillaspy, Hilla Ben-David, and Wilhelm Gruissem, Fruits: A Developmental Perspective, The Plant Cell, Vol. 5, 1439-1451
- Nitsch, J. P. (1953). The Physiology of Fruit Growth. Annual Review of Plant Physiology, 4(1), 199–236.doi:10.1146/annurev.pp.04.060153.0012
- Rahul Kumar, Ashima Khurana, Arun K. Sharma, Role of plant hormones and their interplay in development and ripening of fleshy fruits, *Journal of Experimental Botany*, Volume 65, Issue 16, August 2014, Pages 4561– 4575, https://doi.org/10.1093/jxb/eru277
- Robert, H.S. Molecular Communication for Coordinated Seed and Fruit

Development: What Can We Learn from Auxin and Sugars? *Int. J. Mol. Sci.* 2019, *20*, 936.

Unit 6:

- Golubkina, N., Zamana, S., Seredin, T., Poluboyarinov, P., Sokolov, S., Baranova, H., Krivenkov, L., Pietrantonio, L. and Caruso, G., 2019. Effect of Selenium Biofortification and Beneficial Microorganism Inoculation on Yield, Quality and Antioxidant Properties of Shallot Bulbs. Plants, 8(4), p.102.
- Lovat, C., Nassar, A.M., Kubow, S., Li, X.Q. and Donnelly, D.J., 2016. Metabolic biosynthesis of potato (Solanum tuberosum L.) antioxidants and implications for human health. Critical reviews in food science and nutrition, 56(14), pp.2278-2303.
- Mak, Y.W., Chuah, L.O., Ahmad, R. and Bhat, R., 2013. Antioxidant and antibacterial activities of hibiscus (*Hibiscus rosa-sinensis* L.) and Cassia (Senna bicapsularis L.) flower extracts. Journal of King Saud University-Science, 25(4), pp.275-282.
- Kasote, D.M., Katyare, S.S., Hegde, M.V. and Bae, H., 2015. Significance of antioxidant potential of plants and its relevance to therapeutic applications. International journal of biological sciences, 11(8), p.982

Unit 7:

- Yahia, E.M. and Carrillo-Lopez, A. eds., 2018. Postharvest Physiology and Biochemistry of Fruits and Vegetables. Woodhead Publishing.
- Valero, D. and Serrano, M., 2010. Postharvest biology and technology for preserving fruit quality. CRC press.
- Wills, R. and Golding, J., 2016. Postharvest: an introduction to the physiology and handling of fruit and vegetables. UNSW press.
- Siddiqui, M.W. ed., 2015. Postharvest biology and technology of horticultural crops: principles and practices for quality maintenance. CRC Press.
- Corpas, F. J., and Palma, J. M. (2018). Nitric oxide on/off in fruit ripening. Plant Biology, 20(5), 805–807.doi:10.1111/plb.12852

Course Code: PP 609 Credit: 2+1

Title: PLANT-MICROBE INTERACTIONS

WHY THIS COURSE?

Plant microbe encounters can be friendly or hostile. Plants are associated with a variety of microorganisms, including endophytes, phylloplane and rhizosphere microbes which provide plants with mineral nutrients and other benefits. In contrast phytopathogens obtain nutrition from plants leading to reduction in plant growth and subsequent killing. Besides the genetic makeup expression of the phenotype is regulated by environment and the plant microbe interaction especially the endophytes. It is also relevant to understand the plant-pathogen and plant-insect interactions to improve tolerance mechanisms by altering specific physiological and biochemical processes. The combined effects of biotic and abiotic are another aspects of importance. Understanding how physiology of plants simultaneously exposed to abiotic stress and pathogens decides the outcome of their interactions is important. The course provides comprehensive information on these aspects. Plant-microbe interaction is an emerging area and PhD scholar must be exposed to this new knowledge which might help in manipulation plant traits and boost crop growth.

AIM OF THIS COURSE

The objective of the course is to provide the understanding how beneficial microbes (endophyte/rhizosphere/phylloplane microbiome) play a role in boosting the plant immune system and thereby stimulate plant health and growth. The course also aims to understand how plant pathogens are able to infect plants and how resistant plants are able to defend themselves. The course covers comprehensive interactive information from physiology, microbiology and genomics.

The course is organized as follows:

No.	Blocks	Units
1.	**Plant Pathogen Interaction**	1. Introduction to Plant Pathogen Interaction
		2. Genetic Basis of Host Pathogen Interaction
		3. Growth Regulators of Plant Defense and Susceptibility
		4. Bioenergetics in Plant Pathogen Interaction
2.	**Plant- Endophytes / Rhizosphere / Phylloplane Microbes Interaction**	1. Interaction of Endophytes/ Rhizosphere/ Phylloplane Microbes with Plants
		2. Role of Endophyte / Rhizospheric / Phylloplane Microbiota in Plant Physiological Processes
		3. Endophyte / Rhizospheric / Phylloplane Microbes in Improving Biotic and Abiotic Stress Tolerance
		4. Bioethics, Biosafety, Intellectual property rights and implications in plant-microbe research
3.	**Microbial Interaction with Plants in The Presence of Abiotic Factors**	1. Disease Triangle and the Contribution of the Environmental Factors in Influencing the Plant-microbe Interaction
		2. Physiological and Molecular Basis for Predisposition or Endurance of Plant during Abiotic-biotic Stress Interaction

LEARNING OUTCOMES

By the end of this course, the student will be able to:

1. understand how beneficial microbes enhance the plant immune system
2. comprehend how beneficial microbes stimulate plant growth

3. describe plant-microbe interaction
4. understand plant defense and susceptibility

BLOCK 1: PLANT PATHOGEN INTERACTION

Unit 1: Introduction to Plant Pathogen Interaction

- Introduction to plant microbe interaction and importance, the concepts of holobiome and hologenome
- Differences between endophytes/ rhizosphere/phylloplane microbes and phytopathogens
- Types of endophytes/rhizosphere/phylloplane microbes, and their classifications

Unit 2: Genetic Basis of Host Pathogen Interaction

- Genetics of immune response, Signal perception, Host-pathogen interaction (bacteria, fungus and virus).
- Nature of resistance to diseases-pathogenecity genes *(pat)* in plant pathogens-disease specific genes *(dsp), avirulence genes (avr), avr gene – coded proteins-structure of avr genes.*
- Transmission of the alarm signal to host defense producers: signal transduction, pathogen elicitors, protein kinases, calcium ions, phosphorylases, phospholipases, ATPases.
- Accumulation of Phytoalexins as a Resistance mechanism- Biosynthesis and

  metabolism of Phytoalexins, Modes of action of Phytoalexins,
- Pathogenesis-Related proteins (PR) and Disease Resistance- intro-Characterization and biological functions of PR proteins, Biosynthesis of PR proteins.

Unit 3: Growth Regulators of Plant Defense and Susceptibility

- Regulation of hormones countering the pathogen infection and toxins modulating the plant physiology
- ABA-SA cross talk and role of JA during plant interaction biotrophic and necrotrophic pathogens respectively

Unit 4: Bioenergetics in Plant Pathogen Interaction

- An overview of energy-capture and energy-utilization processes in higher plant, Energy-capture and utilization process as affected by pathogenic infection.
- Molecular basis of pathogenesis and the process of interaction- classical examples of pathogens causing necrosis, wilts, tumours and soft rots
- Role of primary metabolism in plant-pathogen interaction

BLOCK 2: PLANT- ENDOPHYTES / RHIZOSPHERE / PHYLLOPLANE MICROBES INTERACTION

Unit 1: Interaction of Endophytes/ Rhizosphere/ Phylloplane Microbes with Plants

- Approaches to study endophytic/ rhizosphere /phylloplane microbes bacteria and fungi, Intracellular bacteria ‘Cytobacts’
- Possible mechanisms of host plant genotype influence in recruitment of endophytic microbes vertical / seed transmission;
- Inter-kingdom signaling regulating endophyte/ rhizosphere/phylloplane microbes development
- Adaptation with respect to colonization of endophytes/ rhizosphere/phylloplane microbes

Unit 2: Role of Endophyte / Rhizospheric / Phylloplane Microbiota in Plant Physiological Processes

- Phytohormones role in beneficial endophyte/rhizospheric/phylloplanerecruitment;;
- Hormonal regulation of assimilate partitioning in plant-microbe interactions.
- Plant-Fungus-Bacteria, the three fold interaction for improved plant nutrition

Unit 3: Endophyte / Rhizospheric / Phylloplane Microbes in Improving Biotic and Abiotic Stress Tolerance

- Importance in imparting stress (biotic and abiotic) adaptations, in the regulation of bioactive compound (alkamide) accumulation; acclimatization of root-interacting fungi for improved plant nutrition and stress tolerance;
- Cultivable versus uncultivable endophytes with respect to their extent of tissue colonization and diversity
- Genetic engineering of endophytes for production of industrially important bioactive compounds, endophyte-enrichment technologies in crops for traits manipulation.
- Role of existing microbiome on introduced endophyte, symbiotic microbes and their interaction
- Modern techniques for examining plant-microbe-insect interactions.

Unit 4: Bioethics, Biosafety, Intellectual property rights and implications in plant- microbe research

- DBT biosafety regulations on working with microbial organisms associated with plants
- Standard operating procedure (SOP)
- Committees dealing with biosafety and safe release of microorganisms

BLOCK 3: MICROBIAL INTERACTION WITH PLANTS IN THE PRESENCE OF ABIOTIC FACTORS

Unit 1: Disease Triangle and the Contribution of the Environmental Factors in Influencing the Plant-microbe Interaction

- Disease triangle involving plant-pathogen-environment and the importance of environmental stresses (drought, heat, humidity and soil factors) in influencing the resistance or susceptibility
- Role of environmental factors in influencing establishment and sustenance of introduced beneficial microbes

Unit 2: Physiological and Molecular Basis for Predisposition or Endurance of Plant during Abiotic-biotic Stress Interaction

- Plant-water relations and changes in physiology in deciding the microbe interaction with plants
- Metabolites in deciding the microbe interaction with plants
- Hormonal cross talk, signal transduction, role of R-genes and other defense pathways during the simultaneous exposure to abiotic stress

PRACTICALS

- *In-planta* bacterial/fungal multiplication in plant under drought stress
- Detection of plant pathogens using molecular tools
- Stomatal conductance in plants under drought stress and pathogen stress
- Apoplast isolation from plants subjected to bacterial infection
- Virus induced gene silencing in plants
- Acetylene reduction assays to check nitrogen fixation in plant (The effect of beneficial microbes in plant)
- Biochemical analyses of beneficial and pathogen-effector proteins
- Plant colonization and disease or growth promotion scoring
- In-vivo detection of plant immune responses and their inhibition by effectors
- Estimation of phytoalexins, PR proteins, ACC deaminase and growth hormones in pathogen challenged plants
- Effect of plant microbe interaction on plant physiological processes viz., photosynthesis, chlroroplast, transpiration etc.,

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

RESOURCES

Block 1:

- The plant immune system. By Jonathan D. G. Jones and Jeffery L. Dangl. Nature Vol.

  444, Pages 323–329 (2006)
- Plant immunity: towards an integrated view of plant–pathogen interactions. By Peter

  N. Dodds and John P. Rathjen. Nature Reviews. Genetics. Vol. 11, Pages 539–548 (2010)
- Signaling in Plant-Microbe Interaction. By Barbara Baker, Patricia Zambryski, Brian Staskawicz, S. P. Dinesh-Kumar. Science. Vol. 276 (1997)
- The role of abscisic acid in plant–pathogen interactions. By Brigitte Mauch-Mani and Felix Mauch. Current Opinion in Plant Biology. Vol. 8, Pages

409-414 (2005)

- Salicylic acid in plant defence—the players and protagonists. Current Opinion in Plant Biology. By Gary Loake and Murray Grant. Vol. 10, Pages 466-472 (2007)

Block 2:

- Microbial Communities and Their Interactions in Soil and Rhizosphere Ecosystems. By Angela D. Kent and Eric W. Triplett. Annual Review of Microbiology. Vol 56, Pages 211-236 (2002)
- Microbial interactions and biocontrol in the rhizosphere. By John M. Whipps. Journal of Experimental Botany, Vol 52, Pages 487–511 (2001)
- The importance of the microbiome of the plant holobiont. By Philippe Vandenkoornhuyse, Achim Quaiser, Marie Duhamel, Amandine Le Van, Alexis Dufresne. New Phytologist. Vol. 206, Pages 1196-1206 (2015)

Block 3:

- Abiotic and biotic stress combinations. By Nobuhiro Suzuki, Rosa M. Rivero, Vladimir Shulaev, Eduardo Blumwald and Ron Mittler. New Phytologist. Vol. 203, Pages 32-4. (2014)
- The interaction of plant biotic and abiotic stresses: from genes to the field. By Nicky

  J. Atkinson and Peter E. Urwin. Journal of Experimental Botany, Vol 63, Pages 3523– 3543. (2012)

General Source Information

- Cooperative Adaptations and Evolution in Plant-Microbe Systems by Tatiana Matveeva, Nikolai Provorov, Jari P.T. Valkonen , Frontiers Media SA
- Endophytes: Crop Productivity and Protection, Editors: Maheshwari, Dinesh K., Annapurna, K. (Eds.), 2017, ISBN 978-3-319-66544-3; Springer
- Signaling in the Phytomicrobiome by Donald L. Smith, Valérie Gravel, Étienne Yergeau Frontiers Media SA
- Advances in Endophytic Research, 2014, Editors: Verma, Vijay C., Gange, Alan (Eds.), ISBN 978-81-322-1575-2; Springer
- Microbial Root Endophytes, Editors: Schulz, Barbara J.E., Boyle, Christine J.C., Sieber, Thomas N. (Eds.) , 2004, ISBN 978-3-540-33526-9; Springer
- Plant-Microbe Interaction: An Approach to Sustainable Agriculture Editors: Choudhary, Devendra K., Varma, Ajit, Tuteja, Narendra (Eds.), 2016, ISBN 978-981- 10-2854-0; Springer
- Insect-Plant Interactions, 1986, Editors: Miller, James R., Miller, Thomas A. (Eds.)
- Molecular Aspects of Insect-Plant Associations, Authors: Ahmed, S., Brattsten, L.B. ISBN 978-1-4613-1865-1 (Springer).
- The Biology of Plant-Insect Interactions: A Compendium for the Plant Biotechnologist 1st Edition, byChandrakanth Emani, 2018, ISBN 9781498709736 - CAT# K25008, CRC Press.

- Emerging Tools for Emerging Symbioses—Using Genomics Applications to Studying Endophytes by Mysore V. Tejesvi, Anna Maria Pirttilä, A. Carolin Frank Frontiers Media SA
- Advances in Plant-Hemipteran Interactions, by Jyoti Shah, Linda Walling Frontiers Media SA
- Jeng-sheng Huang, 2009, Plant Pathogenesis and Resistance (Biochemistry and Physiology of Plant-Microbe Interactions), Kluwer Academic Publishers.
- Peter R Day, 1973, Genetics of Host Parasite Interaction,W.HFreeeman and Company.
- P. D Sharma, 2006, Plant Pathology, Narosa Publishing House Pvt. Ltd.
- A.Mahadevan, 1979, Physiology of Host-Pathogen Interaction, Today and Tomorrow Printers and Publishers.
- Edward A. Stainhaus, 1963, Insect Pathology, Academic Press, New York and London.
- Follett, P. A. (2017), Insect-plant interactions: host selection, herbivory, and plant resistance – an introduction. EntomolExpAppl, 162: 1-3. doi:10.1111/eea.12524.
- Ryan, R. P., Kieran G., Ashley, F., David, J. R., and David, N. D., 2007, Bacterial endophytes: recent developments and applications. FEMS Microbiol. Lett.,278: 1–9.
- Bringel, F. and Couée, I., 2015, Pivotal roles of phyllosphere microorganisms at the interface between plant functioning and atmospheric trace gas dynamics. Front. Microbiol.6:486. doi: 10.3389/fmicb.2015.00486.
- Lugtenberg, B. (Ed.). 2015, Principles of plant-microbe interactions**.** doi: https://doi.org/10.1007/978-3-319-08575-3.
- Velmourougane, K., Saxena, G., Prasanna, R., 2017, Plant-microbe interactions in the rhizosphere: mechanisms and their ecological benefits. In: Singh D., Singh H., Prabha R. (eds) Plant-Microbe Interactions in Agro-Ecological Perspectives. Springer, Singapore. doi:https://doi.org/10.1007/978-981-10-6593-4_7.
- Schikora, A. (Ed.). 2018, Plant-microbe interactions in the rhizosphere. Caister academic press. doi: https://doi.org/10.21775/9781912530007.

Course Code: PP 610 **Credit: 2+0**

Title: WEED BIOLOGY AND PHYSIOLOGY OF HERBICIDE ACTION

WHY THIS COURSE?

Weeds pose a serious threat to Crop production leading to a yield loss ranging from 30% to sometimes total failure. Weed management is a significant input on part of the producers. Chemical weed management through herbicides have been the most effective among various methods. Various herbicides with different modes of actions are used to control weeds. Prolonged chemical control has led to adverse environmental consequences and development of herbicide resistance. There is a need to understand the biology of weeds as well as herbicide actions at physiological and molecular levels for resistance management as well as development of more effective and less harmful chemicals for weed management. The aim of this course will be to apprise the students about these aspects of chemical weed control.

AIM OF THIS COURSE

The course is designed to provide both basic and applied knowledge on the weeds. It will help to understand the fundamental physiology, biochemistry, and molecular biology of herbicides and their effects on plants; To study the physiological and molecular mechanisms of herbicide resistance. This course will provide knowledge on biology of weeds, classification and mode of action of herbicides, herbicide resistance and its management and environment friendly weed management strategies.

The course is organized as follows:

No.	Blocks	Units
1.	**Weed Biology**	5. Weed Biology and its Importance in Weed Management
		6. Life Cycle and Population Dynamics of Weeds
		7. Crop Weed Competition
2.	**Physiology of Herbicide Action**	1. Introduction to Herbicides
		2. Mechanism of Action of Herbicides
		3.Herbicide Resistance and its Management

LEARNING OUTCOMES

After successful completion of this course, the students are expected to be able to:

- Understand the importance of weed biology in weed management
- Understand the mechanism of herbicide action
- Understand the problem of herbicide resistance development
- Appreciate and suggest sustainable weed management strategies

BLOCK 1: WEED BIOLOGY

Unit 1: Weed Biology and its Importance in Weed Management

Introduction to weeds, Classification of weeds, Yield losses caused by weeds, Environmental impacts of invasive weed species, Aspects of Weed biology, Germination, Dormancy and growth behaviour of weed species, Effect of environmental factors on weeds, Adaptation of weeds to different ecologies

Unit 2: Life Cycle and Population Dynamics of Weeds

Growth duration and reproductive potential of weed species, Population dynamics, Weed Shift due to weed management, weed Seed Bank,

Unit 3: Crop Weed Competition

Understanding the nature of crop-weed competition, critical stages of crop weed competition, growth stages of weeds for improved control by herbicides

BLOCK 2: PHYSIOLOGY OF HERBICIDE ACTION

Unit1: Introduction to Herbicides

Introduction, Chemistry and classification of herbicides by mechanism of action, HRAC Classification, Site of Actions, Application techniques, doses, active ingredients, formulations, Absorption and translocation of soil and foliar applied herbicides, Methods to increase the efficiency of soil and foliar applied herbicide – role of membranes, adjuvants, surfactants, synergists,

Unit 2 :Mechanism of Action of Herbicides

Physiological and biochemical effects of herbicides: Effects on membrane structure and functions, cell division and cell development, Effects on chloroplast, photosynthesis, respiration, protein synthesis, synthesis of lipids, Molecular mechanism of action, Molecular mechanisms of herbicide resistance in relation to chloroplast gene expression,

Unit 3. Herbicide Resistance and its Management

Herbicide resistance-Definition, history, magnitude; Mechanisms of resistance: Target site and non-target site, cross and multiple resistances, Role of management practices on resitance development, Resistance management: Strategies; HR crops, Super weeds,

TEACHING METHODS / ACTIVITIES

- Lectures
- Assignment (Reading/Writing)
- Text Books / reference books and materials
- Student presentations

RESOURCES

- Inderjit (Ed). 2004. Weed Biology and Management. Springer Netherlands
- Monaco, TJ, Weller SC, Ashton FM. 2002. Weed Science : Principles and practices. John Wiley and Sons Inc., New York
- De Prado R, Jorrin J, and Garcia-Torres L. 1997. Weed and Crop resistance to Herbicides. Kluwer academic Publishers, The Netherlands.
- Heap I. (2018.). The international Survey of Herbicide Resistant Weeds. www.weedscience.com
- Herbicide Handbook of the Weed Science Society of America, 9th Edition. 2008. http://wssa.net.
- Devine, M.D., S.O. Duke, and C. Fedtke. 1993. Physiology of Herbicide Action. Prentice-Hall, Inc. Englewood, NJ. 441 pp
- Zimdahl, R L .2007. Fundamentals of Weed Science (Third Edition). Academic Press- Elsevier, USA.

MOLECULAR BIOLOGY AND BIOTECHNOLOGY

Course Title with Credit Load for M.Sc. in Molecular Biology and Biotechnology

Course Code	Course Title	Credit Hours
	Major: 20 credits	
	(**12 credits of core + 8 credits of optional**)	
MBB 501	Principles of Biotechnology	3+0
MBB 502	Fundamentals of Molecular Biology*	3+0
MBB 503	Molecular Cell Biology*	3+0
MBB 504	Techniques in Molecular Biology I*	0+3
MBB 505	Omics and Systems Biology*	2+1
MBB 506	Plant Genetic Engineering	3+0
MBB 507	Techniques in Molecular Biology II	0+3
MBB 508	Introduction to Bioinformatics	2+1
MBB 509	Plant Tissue culture	2+1
MBB 510	Microbial and Industrial Biotechnology	2+1
MBB 511	Molecular Plant Breeding	2+1
MBB 512	IPR, Bio-safety and Bioethics	2+0
MBB 513	Immunology and Molecular Diagnostics	3+0
MBB 514	Nano Biotechnology	2+1
MBB 515	Environmental Biotechnology	3+0
MBB 516	Bio-entrepreneurship#	1+0
MBB 517	Stress Biology and Genomics#	2+0
MBB 518	Gene Regulation#	2+0
	Minor (8 credits) – from the following disciplines Biochemistry Genetics and Plant Breeding Microbiology Plant Physiology Plant Pathology Entomology Bioinformatics Plant Genetic Resources Any other related discipline	

Course Code	Course Title	(L+P)
	Basic Supporting (6 credits) from the following disciplines Biochemistry Microbiology Genetics and Plant Breeding Statistics Bioinformatics Computer Applications	
	Common courses	5
MBB591	Master’s Seminar	0+1
MBB599	Master’s Research	0+30
	Total	**70**

*Core Courses; # New Courses

I. **Course Title** : **Principles of Biotechnology**

II. **Course Code** : **MBB 501**

III. **Credit Hours** : **3+0**

IV. **Aim of the course**

- To understand the basics of Molecular biology, plant and microbial Biotechnology
- Importance and applications in agriculture, case studies and success stories
- Public education, perception, IPR and related issues

V. **Theory**

Unit I (12 Lectures)

History, scope and importance of Biotechnology; Specializations in Agricultural Biotechnology: Genomics, Genetic engineering, Tissue Culture, Bio-fuel, Microbial Biotechnology, Food Biotechnology etc. Basics of Biotechnology, Primary metabolic pathways, Enzymes and their activities.

Unit II (16 Lectures)

Structure of DNA, RNA and protein, their physical and chemical properties. DNA function: Expression, exchange of genetic material, mutation. DNA modifying enzymes and vectors; Methods of recombinant DNA technology; Nucleic acid hybridization; DNA/RNA libraries; Applications of gene cloning in basic and applied research, Plant transformation: Gene transfer methods and applications of GM crops.

Unit III (8 Lectures)

Molecular analysis of nucleic acids -PCR and its application in agriculture and industry, Introduction to Molecular markers: RFLP, RAPD, SSR, SNP etc, and their applications; DNA sequencing, different methods; Plant cell and tissue culture techniques and their applications. Introduction to genomics, transcriptomics, ionomics, metabolomics and proteomics. Plant cell and tissue culture techniques and their applications.

Unit IV (12 Lectures)

Introduction to emerging topics: Genome editing, gene silencing, Plant microbial interactions, Success stories in Biotechnology, Careers and employment in biotechnology. Public perception of biotechnology; Bio-safety and bioethics issues; Intellectual property rights in biotechnology.

Suggested Reading

- Watson JD, Baker TA, Bell SP, Gann A, Levine M and Losick R. 2014. *Molecular Biology of the Gene*, 7th edition, Cold Spring Harbor Laboratory Press, New York
- Brown T A. 2010. *Gene Cloning and DNA analysis an Introduction* 6th edition, Wiley Blackwell
- Primrose SB and Twyman R. 2006. *Principles of gene Manipulation* 7th edition, Wiley Blackwell
- Singh BD. 2012. *Biotechnology: Expanding Horizons* 4th edition, Kalyani publisher, New Delhi, India

I. **Course Title** : **Fundamentals of Molecular Biology**

II. **Course Code** : **MBB 502**

III. **Credit Hours** : **3+0**

IV. **Aim of the course**

- To understand the basics of DNA, RNA, structure, types and chromatin assembly.
- To get insights into the Central Dogma, basic cellular processes, role of mutation and recombination.
- To understand different levels of gene regulation and the pathways involved.

V. **Theory**

- **Unit I (8 Lectures)**

  Historical developments of molecular biology, Nucleic acids as genetic material, Chemistry and Nomenclature of nucleic acids; Structure of DNA: primary structure; secondary structure, Forms of DNA: A, B, Z and their function; Structure and Types of RNA Genome organization in prokaryotes and eukaryotes; DNA Topology; DNA re-association kinetics, Types of repeat sequences.

- **Unit II (10 Lectures)**

  Central dogma of Molecular Biology; DNA replication- Classical experiments, Models of DNA replication; DNA replication, Origin and Steps in DNA replication - initiation, elongation and termination; Enzymes and accessory proteins and their mechanisms; Eukaryotic DNA replication in brief. Types of DNA damages and mutations; DNA repair mechanisms, Recombination: Homologous and non-homologous, Genetic consequences.

- **Unit III (8 Lectures)**

  Prokaryotic transcription, initiation, elongation and termination, promoters, Structure and function of eukaryotic RNAs and ribosomal proteins. Eukaryotic transcription – RNA polymerase I, II and III, Elongation and Termination, Eukaryotic promoters and enhancers, Transcription factors, Post transcriptional processing, Splicing: Catalytic RNAs, RNA stability and transport, RNA editing.

- **Unit IV (10 Lectures)**

  Genetic code and its characteristics, Universal and modified genetic code and its characteristics, Wobble hypothesis; Translational machinery; Ribosomes in prokaryotes and Eukaryotes. Initiation complex formation, Cap dependent and Cap independent initiation in eukaryotes, Elongation: translocation, transpeptidation and termination of translation; Co- and Post-translational modifications of proteins; Translational control; Protein stability -Protein turnover and degradation.

- **Unit V (12 Lectures)**

  Gene regulation in prokaryotes, Constitutive and Inducible expression, small molecule regulators; Operon concept: *lac* and *trp* operons, attenuation, antitermination, stringent control. Gene regulation in eukaryotes– regulatory RNA and RNA interference mechanisms, Silencers, insulators, enhancers, mechanism of silencing and activation; Families of DNA binding transcription factors: Helix -turn- helix, helix-loop-helix etc. Epigenetic regulations

Suggested Reading

- Nelson DL and Cox M.M. 2017. *Lehinger's Principles of Biochemistry*, 7th edition, W H Freeman Publication New York.

- Krebs, J.E., Goldstein, E.S., Kilpatrick, S.T. 2017. *Lewin's Genes* XII 12th edition, Jones & Bartlett Learning publisher, Inc.
- Watson, J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M and Losick R. 2014. *Molecular Biology of the Gene,* 7th edition, Cold Spring Harbor Laboratory Press, New York.
- Alberts, B. 2017. *Molecular Biology of the Cell* 5th edition, WW Norton & Co, Inc.
- Allison, L.A. 2011. *Fundamentals of Molecular Biology*. 2nd Edition, John Wiley and Sons.

I. **Course Title : Molecular Cell Biology**

II. **Course Code : MBB 503**

III. **Credit Hours : 3+0**

IV. **Aim of the course**

- To understand the basics structure and function of plant and animal cell
- To get insights into the basic cellular processes, transport, signalling, cell movement, cell division and general regulation mechanisms.

V. **Theory**

- **Unit I (8 Lectures)**

  Origin of life, History of cell biology, Evolution of the cell: endo-symbiotic theory, tree of life, General structure and differences between prokaryotic and eukaryotic cell; Similarities and distinction between plant and animal cells; different kinds of cells in plant and animal tissues.

- **Unit II (8 Lectures)**

  Cell wall, cell membrane, structure and composition of bio-membranes, Structure and function of major organelles: Endoplasmic reticulum Ribosomes, Golgi apparatus, Mitochondria, Chloroplasts, Lysosomes, Peroxisomes, Micro-bodies, Vacuoles, Nucleus, Cyto-skeletal elements.

- **Unit III (12 Lectures)**

  Membrane transport; Diffusion, osmosis, ion channels, active transport, mechanism of protein sorting and regulation of intracellular transport, transmembrane and vesicular transport - endocytosis and exocytosis; General principles of cell communication: hormones and their receptors, signaling through G-protein coupled receptors, enzyme-linked receptors; signal transduction mechanisms and regulation, Cell junctions, Cell adhesion, Cell movement; Extracellular matrix.

- **Unit IV (10 Lectures)**

  Chromatin structure, Cell division and regulation of cell cycle; Mechanisms of cell division, Molecular events at M phase, mitosis and cytokinesis, Ribosomes in relation to cell growth and division, Extracellular and intracellular Control of Cell Division; abnormal cell division: cancer- hallmarks of cancer and role of oncogenes and tumor suppressor genes in cancer development - Programmed cell death (Apoptosis).

- **Unit V (10 Lectures)**

  Morphogenetic movements and the shaping of the body plan, Cell diversification, cell memory, cell determination, and the concept of positional values; Differentiated cells and the maintenance of tissues and organ development; Stem cells: types and applications; Basics of Animal development in model organisms (*C. elegans*; *Drosophila*); Plant development.

Suggested Reading

- Alberts, B. 2017. *Molecular Biology of the Cell* 5th edition, WW Norton & Co, Inc.
- Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A., Martin, K.C., 2016. *Molecular Cell Biology* 8th Edition. W.H. Freeman & Co. New York.
- Alberts, B., Bray, D., Lewis, J., Raff, M., Roberts, K., Hopkin, K., Johnson, A., Walter, P., 2013 *Essential of Cell Biology*, WW Norton & Co, Inc.
- Cooper, G.M. and Hausman, R.E. 2013. *The cell: A Molecular Approach* 6th edition, Sinauer Associates, Inc.

I. **Course Title : Techniques in Molecular Biology I**

II. **Course Code : MBB 504**

III. **Credit Hours : 0+3**

IV. **Aim of the course**

- To get a basic overview of molecular biology techniques, good lab practices and recombinant DNA technology
- To get a hands on training in chromatography, protein analysis, nucleic acid analysis, bacterial and phage genetics

Practicals

- Good lab practices, preparation of buffers and reagents.
- Principle of centrifugation and spectrophotometry.
- Growth of bacterial culture and preparation of growth curve, Isolation of Genomic DNA from bacteria.
- Isolation of plasmid DNA from bacteria.
- Growth of lambda phage and isolation of phage DNA.
- Isolation and restriction of plant DNA (e.g. Rice / Moong / Mango / Merigold).
- Quantification of DNA by (a) Agarose Gel electrophoresis and (b) Spectrophotometry
- PCR using isolated DNA.
- PAGEGel electrophoresis.
- Restriction digestion of plasmid and phage DNA, ligation, Recombinant DNA construction.
- Transformation of *E. coli* and selection of transformants
- Chromatographic techniques
  a. TLC
  b. Gel Filtration Chromatography,
  c. Ion exchange Chromatography,
  d. Affinity Chromatography
  - Dot blot analysis, Southern hybridization, Northern hybridization.
  - Western blotting and ELISA.
  - Radiation safety and non-radio isotopic procedure.

Suggested Reading

- Sambrook, J., and Russell, R.W. 2001. *Molecular Cloning: A Laboratory Manual* 3rd Edition, Cold spring harbor laboratory press, New York.
- Wilson, K., and Walker, J., 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th edition, Cambridge University Press.
- Ausubel FM, Brent R, Kingston RE, Moore DD, Seidman JG, Smith JA and Struhl K. 2002. *Short Protocols in Molecular Biology* 5th edition, Current Protocols publication.

I. **Course Title : Omics and Systems Biology**

II. **Course Code : MBB 505**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

- To get a basic overview of genomics, proteomics, ionomics and metabolomics
- To get a primary information on the application of omics science across the industry

V. **Theory**

- **Unit I (8 Lectures)**

  Different methods of genome sequencing, principles of various sequencing chemistries, physical and genetic maps, Comparative and evolutionary genomics, Organelle genomics, applications in phylogenetics, case studies of completed genomes, preliminary genome data analysis, basics of ionomics analysis, different methods

- **Unit II (6 Lectures)**

  Protein-basics: primary-, secondary- and tertiary structure, Basics of X-ray crystallography and NMR, Principal and Applications of mass spectrometry, Proteomics: Gel based and gel free, Basics of software used in proteomics, MASCOT, PD-Quest, etc., Study of protein interactions, Prokaryotic and yeast-based expression system and purification

- **Unit III (6 Lectures)**

  Metabolomics and its applications, Use of 1D/2D NMR and MS in metabolome analysis, Multivariate analysis and identification of metabolite as biomarkers, Study of ionome using inductively coupled plasma – mass spectroscopy (ICP-MS), X-Ray Fluorescence (XRF), Neutron activation analysis (NAA), Data integration using genome, transcriptome, proteome, metabolome and ionome with phenome.

- **Unit IV (6 Lectures)**

  Introductory systems Biology - The biochemical models, genetic models and systems model, Molecules to Pathway, Equilibrium binding and cooperatively – Michaelis- Menten Kinetics, Biological oscillators, Genetic oscillators, Quorum Sensing, Cell-cell communication, *Drosophila* Development, Pathways to Network, Gene regulation at a single cell level, transcription network, REGULATORY CIRCUITS, Negative and positive auto-regulation, Alternative Stable States, Bimodal Switches, Network building and analysis

Practical (12)

- Isolation of HMW DNA and a brief overview of sequencing, Primary information on genome data analysis.

- BSA Standard curve preparation, Extraction of protein and estimation methods.
- Quantification of proteins from different plant tissues using spectrophotometry.
- 2-D Gel Electrophoresis, 2-D Image analysis.
- Experiments on protein-protein interaction (Yeast 2-hybrid, Split Ubiquitin system).
- Demonstration on MALDI-TOF.
- Demonstration of ICP-MS, AAS, Nitrogen estimation using various methods.

Suggested Reading

- Primrose, S.B. and Twyman, R. 2006. *Principles of Gene Manipulation* 7th edition, Wiley Blackwell
- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press.

I. **Course Title : Plant Genetic Engineering**

II. **Course Code : MBB 506**

III. **Credit Hours : 3+0**

IV. **Aim of the course**

- To get a basic overview of molecular cloning, vectors and genomic library construction.
- To get anoverview of PCR and its applications, sequencing, gene knockouts, transgenics etc.

V. **Theory**

- **Unit I (10 Lectures)**

  Historical background, Restriction Enzymes; DNA Modifying enzymes, ligase, T4 DNA polymerase, Polynucleotide kinase etc, Cohesive and blunt end ligation; Labeling of DNA: Nick translation, Random priming, Radioactive and non-radioactive probes, Hybridization techniques: Northern, Southern and Colony hybridization, Fluorescence in situ hybridization; Chromatin Immunoprecipitation; DNA-Protein Interactions: Electromobility shift assay.

- **Unit II (14 Lectures)**

  Plasmids; Bacteriophages; M13, Phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Animal Virus derived vectors-SV-40; Expression vectors; pMal, pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag, etc.; Baculovirus vectors system, Plant-based vectors, Ti and Ri plasmids as vectors, Yeast vectors, Shuttle vectors. Transformation; Construction of libraries; Isolation of mRNA and total RNA; cDNA and genomic libraries; cDNA and genomic cloning, Jumping and hopping libraries, Protein-protein interactive cloning and Yeast two-hybrid system; Phage display; Principles in maximizing gene expression; Codon optimization for heterologous expression. Introduction of DNA into mammalian cells; Transfection techniques

- **Unit III (12 Lectures)**

  Principles of PCR, Primer design, DNA polymerases, Types of PCR – multiplex, nested, reverse transcriptase, real time PCR, touchdown PCR, hot start PCR, colony PCR, cloning of PCR products; T- vectors; Applications of PCR in gene recombination, Site-specific mutagenesis, in molecular diagnostics; Viral and bacterial detection; Mutation detection: SSCP, DGGE, RFLP, Oligo Ligation Assay.

- **Unit IV (12 Lectures)**

  Genetic transformation of plants: DNA delivery – *Agrobacterium* mediated method. Direct DNA delivery – chemical mediated electroporation and particle bombardment. Vectors and transgene design - Promoters and Marker genes. Chloroplast transformation. Development of marker-free plants. Analysis of transgenic plants – molecular and Biochemical assays, genetic analysis - Identification of gene integration site - Advance methods – *cis* genesis, intragenesis and targeted genome modification – ZFN, TALENS and CRISPR. Application of transgenic technology.

Suggested Reading

- Brown, T.A. 2010. *Gene Cloning and DNA Analysis an Introduction.* 6th edition, Wiley Blackwel.
- Primrose, S.B. and Twyman, R. 2006. *Principles of Gene Manipulation* 7th edition, Wiley Blackwell.
- Sambrook, J., and Russell, R.W. 2001. *Molecular cloning: A laboratory manual* 3rd Edition, Cold spring harbor laboratory press, New York.
- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press.

I. **Course Title : Techniques in Molecular Biology II**

II. **Course Code : MBB 507**

III. **Credit Hours : 0+3**

IV. **Aim of the course**

- To get a basic overview of molecular biology techniques, good lab practices and molecular markers.
- To get a hands on training in RNAi, microarrays, yeast2 hybrid and immunological techniques.

V. **Practicals**

- Construction of gene libraries (cDNA and Genomics).
- Synthesis and cloning of cDNA.
- Real time PCR and interpretation of data.
- Molecular markers
  i. RAPD.
  ii. SSR.
  iii. AFLP / ISSR and their analysis.
- Case study of SSR markers - construction of linkage map.

- QTL analysis using genotypic data based on SSR.
- SNP identification and analysis.
- Microarray studies and use of relevant software.
- Proteomics
  i. 2D gels,
  ii. Mass spectrometry
- RNAi - designing of construct, phenotyping of the plant.
- Yeast 1 and 2-hybrid interaction.
- Generation and screening of mutants.
- Transposon mediated mutagenesis.
- Immunology and molecular diagnostics: Ouchterlony double diffusion,
- Immunoprecipitation, Radiation Immunodiffusion, Immunoelectrophoretic, Rocket
- Immunoelectrophoretic, Counter Current Immunoelectrophoretic, ELISA, Latex
- Agglutination, Immunohistochemistry.

Suggested Reading

- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press
- Bonifacino, J. S., Dasso, M., Harford, J. B., Liipincott-Schwartz, J., and Yamada, K. M. 2004. *short protocols in Cell Biology*. John Wiley & Sons, New Jersey
- Hawes, C., and Satiat-Jeunemaitre, B. 2001. *Plant Cell Biology: Practical Approach*. Oxford University Press, Oxford
- Sawhney, S.K., Singh, R. 2014. *Introductory Practical Biochemistry*, Alpha science international limited

I. **Course Title : Introduction to Bioinformatics**

II. **Course Code : MBB 508**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

- To get a basic overview of computational techniques related to DNA, RNA and protein analysis.
- To get a hands on training in software's and programs used to analyse, assemble or annotate genomes, phylogenetics, proteomics etc.

V. **Theory**

- **Unit I (8 Lectures)**

  Bioinformatics basics, scope and importance of bioinformatics; Biological databases for DNA and Protein sequences -PIR, SWISSPROT, GenBank, DDBJ, secondary database, structural databases –PDB, SCOP and CATH, Specialized genomic resources, Microarray database.

- **Unit II (10 Lectures)**

  Bioinformatics Tools Facilitate the Genome-Wide Identification of Protein-Coding Genes, Sequence analysis, Sequence submission and retrieval system-SEQUIN, BANKit, SAKURA, Webin, Sequence alignment, pair wise alignment techniques, multiple sequence alignment; Tools for Sequence alignment- BLAST and its variants; Phylogenetic analysis- CLUSTAL X, CLUSTAL W, Phylip, Tcoffee

- **Unit III (10 Lectures)**

  Sequencing of protein; Protein secondary structure prediction- Chousfasman, GOR Method, Protein 3DStructure Prediction: Evaluation of models- Structure validation and refinement - Ramachandran plot, Force field calculations, SAVES. Protein function prediction- sequence and domain based, Primer designing- principles and methods.Drug discovery**,** Structure Based Drug Design- Rationale for computer-aided drug designing, basic principles, docking, QSAR.

Practical (12 Lectures)

- Usage of NCBI resources
- Retrieval of sequence/structure from databases and submission
- Different Databases, BLAST exercises.
- Assembly of DNA and RNA Seq data
- Annotation of assembled sequences,Phylogenetics and alignment
- Visualization of structures, Docking of ligand receptors
- Protein structure analysis and modeling

Suggested Reading

- Attwood, T.K., and Parry-Smith, D. J. 2004. *Introduction to Bioinformatics*, Pearson Education (Singapore) Pvt. Ltd.
- David Edwards (Ed.) 2007. *Plant Bioinformatics: Methods and Protocols*. Humana Press, New Jersey, USA. Biotechnology and Bioinformatics: Molecular Biology and Biotechnology
- Mount, D.W. 2004. *Bioinformatics: Sequence and Genome Analysis*. 2nd Revised edition Cold Spring Harbor Laboratory Press, U.S.
- Pevsner J. 2009. *Bioinformatics and Functional Genomics*, 2nd edition, Wiley-Blackwell.

I. **Course Title : Plant Tissue Culture**

II. **Course Code : MBB 509**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

- To provide insight into principles of plant cell culture and genetic transformation.
- To get a hands on training in basic plant tissue culture techniques, callusing, micropropagation and analysis.

V. **Theory**

- **Unit I (12 Lectures)**

  History of plant tissue culture, principle of Totipotency; Tissue culture media; Plant hormones and morphogenesis; Direct and indirect organogenesis; Direct and indirect somatic embryogenesis; Applications of plant tissue culture; National certification and Quality management of TC plants; Genetic Fidelity testing and Virus indexing methods – PCR, ELISA

- **Unit II (12 Lectures)**

  Micropropagation of field and ornamental crops; Virus elimination by meristem culture, meristem tip culture and micrografting; Androgenesis and gynogenesis - production of androgenic and gynogenic haploids - diploidization; Protoplast culture - isolation and purification; Protoplast culture; Protoplast fusion; Somatic hybridization - Production of Somatic hybrids and Cybrids; Wide hybridization - embryo culture and embryo rescue techniques; Ovule, ovary culture and endosperm culture.
- **Unit III (12 Lectures)**

  Large-scale cell suspension culture - Production of alkaloids and other secondary metabolites- techniques to enhance secondary metabolite production, Somaclonal and gametoclonal variations – causes and applications; Callus culture and *in vitro* screening for stress tolerance; Artificial seeds, *In vitro* germplasm storage and cryo-preservation. Commercial Tissue Culture: Case studies and success stories, Market assessment; project planning and preparation, economics, government policies

Practical (12)

- Preparation of stocks - macronutrients, micronutrients, vitamins and hormones, filter sterilization of hormones and antibiotics. Preparation of Murashige and Skoog medium.
- Micro-propagation of plants by nodal and shoot tip culture.
- Embryo culture to overcome incompatibility, Anther culture for haploid production.
- Callus induction in tobacco leaf discs, regeneration of shoots, root induction, role of hormones in morphogenesis.
- Acclimatization of tissue culture plants and establishment in greenhouse.
- Virus indexing in tissue culture plants. (Using PCR and ELISA).
- Plan of a commercial tissue culture unit.

Suggested Reading

- Razdan, M.K. 2003. *Introduction to plant tissue culture*, 2nd edition, Oxford publications group
- Butenko, R.G. 2000. *Plant Cell Culture* University Press of Pacific
- Herman, E.B. 2008. *Media and Techniques for Growth, Regeneration and Storage*, Agritech Publications, New York, USA.
- Bhojwani, S.S and Dantu P. 2013. *Plant Tissue Culture – An Introductory Text*. Springer Publications.
- Gamborg, O.L and G.C. Philips (eds.). 2013. *Plant Cell, Tissue and Organ culture-Lab Manual*. Springer Science & Business media.

I. **Course Title : Microbial and Industrial Biotechnology**

II. **Course Code : MBB 510**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

- To familiarize about the various microbialprocesses/systems/activities, which have been used for the development of industrially important products/processes.

V. **Theory**

- **Unit (8 Lectures)**

  Introduction, scope and historical developments; Isolation, screening and genetic improvement (involving classical approaches) of industrially important organisms.

- **Unit II (8 Lectures)**

  Primary metabolites, production of industrial ethanol as a case study; Secondary metabolites, bacterial antibiotics and non-ribosomal peptide antibiotics as case study; Recombinant DNA technologies for microbial processes; Strategies for development of industrial microbial strains with scale up production capacities; Metabolic pathway engineering of microbes for production of novel product for industry.

- **Unit III (8 Lectures)**

  Microbial enzymes, role in various industrial processes, production of fine chemicals for pharmaceutical industries; Bio-transformations, Bio-augmentation with production of vitamin C as a case study; Bioreactors, their design and types; Immobilized enzymes-based bioreactors; Microencapsulation technologies for immobilization of microbial enzymes.

- **Unit IV (8 Lectures)**

  Environmental Biotechnology, biotreatment for pollution control, treatment of industrial and other wastes, biomass production involving single cell protein; Bioremediation of soil; Production of eco-friendly agricultural chemicals, bio-pesticides, bio-herbicides, bio-fertilizers, bio-fuels, etc.

Practical

- Isolation of industrially important microorganisms, their maintenance and improvement.
- Lab scale production of industrial compounds such as alcohol, beer, citric acid, lactic acid and their recovery.
- Study of bio-reactors and their operations.
- Production of bio-fertilizers.
- Experiments on microbial fermentation process of antibiotics, bio-pigments, dairy products, harvesting purification and recovery of end products.
- Immobilization of cells and enzymes, studies on its kinetic behavior, growth analysis and Biomass estimation.
- Determination of mass transfer coefficient.

Suggested Reading

- Waites, M.J., Morgan, N.L., Rockey, J.S., Higton, G. 2001. *Industrial Microbiology: An Introduction*, Wiley-Blackwell.
- Slater, A., Scott, N.W., & Fowler, M.R. 2003. *The Genetic Manipulation of Plants*. *Plant Biotechnology Oxford, England: Oxford University Press*.
- Kun, L.Y. (Ed.). 2003. *Microbial biotechnology: principles and applications*. World Scientific Publishing Company.

I. **Course Title: Molecular Plant Breeding**

II. **Course Code : MBB 511**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

- To familiarize the students about the use of molecular biology tools in plant breeding.
- To provide a hands on training in data analysis, diversity analysis and mapping of genes and QTLs.

V. **Theory**

- **Unit I (8 Lectures)**

  Inheritance of qualitative and quantitative traits. Heritability – its estimation, Population structure of self- and cross-pollinated species, Factors affecting selection efficiency. Development of different kinds of segregating populations – F2, F3, BC1F1, BC1F2, BC4F2, RIL (Recombinant Inbred Lines), AIL (Advanced Intercrossed Lines), DH (Di-haploid population), NIL (Near Isogenic lines), NAM (Nested Association Mapping), MAGIC (Multi-parent Advanced Generation Intercross population).

- **Unit II (8 Lectures)**

  Causes of sequence variation and its types, Types of molecular markers and development of sequence based molecular markers – RFLP, AFLP, SCARs, CAPS, SSRs, STMS, SNPs InDel and DARTseq; Inheritance of markers, Linkage analysis using test cross, F2, F3, BC1F1, RIL. Construction of genetic map, Mapping genes for qualitative traits; Genotyping by sequencing and high-density chip arrays.

- **Unit III (8 Lectures)**

  QTL mapping using structured populations; Association mapping using unstructured populations; Genome Wide Association Studies (GWAS), Principle of Association mapping– GWAS-SNP genotyping methods, DART array sequencing, Illumina's Golden Gate Technology, Genotyping by sequencing methods- Fluidigm; GBS, Illumina Hi seq- Nanopore sequencing, Principles and methods of Genomic Selection, Fine mapping of genes/QTL; Development of gene based markers; Allele mining by TILLING and Eco-TILLING.

- **Unit IV (8 Lectures)**

  Tagging and mapping of genes. Bulk segregant and co-segregation analysis, Marker-assisted selection (MAS); Linked, unlinked, recombinant, flanking, peak markers. Foreground and background selection; MAS for gene introgression and pyramiding: MAS for specific traits with examples. Haplotype concept and Haplotype-based breeding; Genetic variability and DNA fingerprinting. Molecular markers in Plant variety protection, IPR issues, hybrid purity testing, clonal fidelity testing and transgenic testing.

Practical

- Construction of linkage map.
- QTL analysis using the QTL cartographer and other software.
- SNP data analysis using TASEEL.
- Detection of haplotype block using SNP data - pLinksoftware.
- Genotyping by sequencing methods –Illumina genotyping platform.
- Marker assisted breeding – MABB case studies quality traits in rice/maize.
- Genome Assisted Breeding in model crops, Genomic Selection models using the morphological and SNP data

Suggested Reading

- Acquaah, G. 2007. *Principles of Plant Genetics and Breeding*, Blackwell Publishing Ltd. USA.
- Weising, K., Nybom, H., Wolff, K., and Kahl, G. 2005. *DNA Fingerprinting in Plants: Principles, Methods and Applications*, 2nd ed. Taylor and Francis Group, Boca Raton, FL.
- Halford, N. 2006. *Plant Biotechnology-Current and future applications of genetically modified crops*, John Wiley and Sons, England.
- Singh, B. D. and Singh, A. K. 2015. *Marker-Assisted Plant Breeding: Principles and Practices* Springer (India) Pvt. Ltd.
- Boopathi, NM. 2013. *Genetic Mapping and Marker Assisted Selection: Basics, Practice and Benefits*. Springer India. p293.

I. **Course Title : IPR, Bio-safety & Bioethics**

II. **Course Code : MBB 512**

III. **Credit Hours : 2+0**

IV. **Aim of the course**

- To familiarize the students about ethical and biosafety issues in plant biotechnology.

V. **Theory**

- **Unit I (10 Lectures)**

  IPR: historical background in India; trade secret; patent, trademark, design& licensing; procedure for patent application in India; Patent Cooperation Treaty (PCT); Examples of patents in biotechnology-Case studies in India and abroad; copyright and PVP; Implications of IPR on the commercialization of biotechnology products, ecological implications; Trade agreements- The WTO and other international agreements, and Cross border movement of germplasms.

- **Unit II (8 Lectures)**

  Biosafety and bio-hazards; General principles for the laboratory and environmental-safety; Biosafety and risk assessment issues; handling and disposal of biohazards; Approved regulatory laboratory practice and principles, The Cartagena Protocol on biosafety; Biosafety regulations in India; national Biosafety Policy and Law; Regulations and Guidelines related to Biosafety in other countries

- **Unit III (8 Lectures)**

  Potential concerns of transgenic plants – Environmental safety and food and feed safety. Principles of safety assessment of Transgenic plants – sequential steps in risk assessment. Concepts of familiarity and substantial equivalence. Risk - Environmental risk assessment – invasiveness, weediness, gene flow, horizontal gene transfer, impact on non-target organisms; food and feed safety assessment – toxicity and allergenicity. Monitoring strategies and methods for detecting transgenics.

- **Unit IV (6 Lectures)**

  Field trials – Biosafety research trials – standard operating procedures, labeling of GM food and crop,Bio-ethics- Mankind and religion, social, spiritual & environmental ethics; Ethics in Biotechnology, labeling of GM food and crop; Biopiracy

Suggested Reading

- Goel, D. and Parashar, S. 2013. *IPR, biosafety, and bioethics*.
- Joshi, R. 2006. *Biosafety and Bioethics*.
- Nambisan, P. 2017. *An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology*.

I. **Course Title : Immunology and Molecular Diagnostics**

II. **Course Code : MBB 513**

III. **Credit Hours : 3+0**

IV. **Theory**

- **Unit I (6 Lectures)**

  Immunity and its classification; Components of innate and acquired immunity; Lymphatic system; Hematopoiesis; Organs and cells of the immune system-primary, secondary and tertiary lymphoid organs Descriptions of Antigens - immunogens, hapten and adjuvants.

- **Unit II (12 Lectures)**

  Immunoglobulins-basic structure, classes & subclasses of immunoglobulins, antigenic determinants; Multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; Principles of cell signaling; Basis of self and nonself discrimination; Kinetics of immune response, memory; B cell maturation, activation and differentiation; Generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; Functional T Cell Subsets; Cell-mediated immune responses, ADCC; Cluster of Differentiations (CDs), Cytokines properties, receptors and therapeutic uses.

- **Unit III (8 Lectures)**

  Phagocytosis; Complement and Inflammatory responses; Major Histocompatibility Complex - MHC genes, MHC and immune responsiveness and disease susceptibility, HLA typing; Antigen processing and presentation-endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; Cell-cell co-operation, Hapten-carrier system

- **Unit IV (10 Lectures)**

  Precipitation, agglutination and complement-mediated immune reactions; Advanced immunological techniques – RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; Surface plasmon resonance, Biosenor assays for assessing ligand – receptor interaction, CMI techniques- lymphoproliferation assay, Mixed lymphocyte reaction, Cell Cytotoxicity assays, Apoptosis, Transgenic mice, Gene knock outs

- **Unit V (12 Lectures)**

  Active and passive immunization; Live, killed, attenuated, sub unit vaccines; Vaccine technology- Role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, Antibody genes and antibody engineering- chimeric and hybrid monoclonal antibodies, Immunity to Infection, Bacteria, viral, fungal and parasitic infections, Hypersensitivity – Type I-IV; Autoimmunity; Types of autoimmune diseases, MHC and TCR in autoimmunity; Transplantation, Immunological basis of graft rejection, immunosuppressive therapy; Tumor immunology – Tumor antigens.

Suggested Reading

- Owen J.A., Punt, J., & Stranford, S. A. 2013. *Kuby immunology* (p. 692). New

York: WH Freeman.

- Kenneth, M., and Weaver, C. 2017. *Janeways Immunobiology*, 9th Edition, New York, USA: Garland Science, Taylor & Francis publisher.
- William, P. 2013. *Fundamental of Immunology*, 7th edition, Lippencott, William and Wilkins publisher.

I. **Course Title : Nano Biotechnology**

II. **Course Code : MBB 514**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

- Understanding the molecular techniques involved in structure and functions of nano-biomolecules in cells such as DNA, RNA and proteins.

V. **Theory**

- **Unit I (8 Lectures)**

  Introduction to Nanotechnology - Nanomaterials - Self-assembly to artificial assembly for creation of useful nanostructures – Bottoms up and Top down approach (Nano rods, nano cages, nanotubes, quantum dots, nanowires, metal/ polymer-based nanostructures) – Preparation and Characterization of nanoparticles (particle size analyzer, microscopy, viz. electron microscopy, atomic force microscopy, etc).

- **Unit (8 Lectures)**

  Cell structure – Bio macromolecules: Types, Structure, Dynamics and interaction with water – Cellular nano machines – cellular transducers, membrane channels, membrane transporters, Membrane motors – Creation of bio-nanostructures (Nano liposomes, Nano micelles, Nanomotors, etc).

- **Unit III (8 Lectures)**

  Chemical, physical and biological properties of biomaterials and bio response: biomineralization, biosynthesis, and properties of natural materials (proteins, DNA, and polysaccharides), structure-property relationships in polymeric materials (synthetic polymers and structural proteins); Aerosol properties, application and dynamics; Statistical Mechanics in Biological Systems,

- **Unit (8 Lectures)**

  Nanoparticular carrier systems; Micro- and Nano-fluidics; Drug and gene delivery system; Microfabrication, Biosensors, Chip technologies, Nano-imaging, Metabolic engineering and Gene therapy.

Practical

- Isolation of enzymes and nucleic acids involved in biosynthesis of nanomaterials
- Synthesis of Gold/silver Nanoparticles by biogenic methods, Synthesis of micelles and inverse micelles
- Synthesis of Carbon Nano-materials by Chemical Vapor Deposition and Sputtering technique
- Preparation of thiolate silver nanoparticles, Purification and measurement of carbon
- nano materials
- Zinc selenide quantum dot preparation, Synthesis of Iron Oxide Nanoparticle
- Thin film preparation by spin coating technique, Synthesis of Nickel metal

nanoparticle by urea decomposition method

- Synthesis of Zinc Oxide nanoparticle

Suggested Reading

- Nalwa, H.S. 2005. *Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology*. American Scientific Publications.
- Niemeyer C.M. and Mirkin C.A. (Eds) 2005. *Nanobiotechnology: Concepts Applications and Perspectives,* Wiley Inter-science publications.
- Cao, G., and Wang, Y. 2004. *Nanostructures and Nanomaterials: Synthesis, Properties and Applications,* Imperial College Press.

I. **Course Title : Environmental Biotechnology**

II. **Course Code : MBB 515**

III. **Credit Hours : 3+0**

IV. **Aim of the course**

- To apprise the students about the role of biotechnology in environment management for sustainable eco-system and human welfare.

V. **Theory**

- **Unit I (8 Lectures)**
- Basic concepts and environmental issues; types of environmental pollution; problems arising from high-input agriculture; methodology of environmental management; air and water pollution and its control; waste water treatment - physical, chemical and biological processes; need for water and natural resource management.
- **Unit II (8 Lectures)**

  Microbiology and use of micro-organisms in waste treatment; biodegradation; degradation of Xenobiotic, surfactants; bioremediation of soil & water contaminated with oils, pesticides and toxic chemicals, detergents etc; aerobic processes (activated sludge, oxidation ditches, trickling filter, rotating drums, etc); anaerobic processes: digestion, filtration, etc.
- **Unit III (8 Lectures)**

  Renewable and non-Renewable resources of energy; energy from solid waste; conventional fuels and their environmental impact; biogas; microbial hydrogen production; conversion of sugar to alcohol; gasohol; biodegradation of lignin and cellulose; biopesticides; biofertilizers; composting; vermiculture etc.
- **Unit IV (8 Lectures)**

  Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by microorganisms; global environmental problems: ozone depletion, UV-B, greenhouse effects, and acid rain; biodiversity and its conservation; biotechnological approaches for the management environmental problems.

Suggested Reading

- Evans, G. M. and Furlong, J. C. 2010. *Environmental Biotechnology: Theory and Application*. 2nd edition, Wiley-Blackwell.
- Jordening HJ and Winter J. 2006. *Environmental Biotechnology: Concepts and Applications*. Wiley-VCH Verlag.

I. **Course Title : Bio-entrepreneurship**

II. **Course Code : MBB 516**

III. **Credit Hours : 1+0**

IV. **Aim of the course**

The objective of this course is to teach students about fundamentals of entrepreneurship, launching a venture or a start up in biotechnology-based theme.

V. **Theory**

- **Unit I (4 Lectures)**

  Scope in biotechnology; types of bio-industries – bio-pharma, bio-agri, bio-services and bio-industrial; Importance of entrepreneurship; introduction to bioentrepreneurship – biotechnology on a global scale; –skills for successful entrepreneur–creativity, leadership, managerial, team building, decision making; opportunities for bio-entrepreneurship- entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Startup & Make in India)

- **Unit II (4 Lectures)**

  Business plan preparation; business feasibility analysis by SWOT, socio-economic costs benefit analysis; funds/ support from various agencies; statutory and legal requirements for starting a company/ venture.

- **Unit III (4 Lectures)**

  Entry and exit strategy; identifying needs of customers; Market linkages, branding issues; developing distribution channels - franchising; policies, promotion, advertising; branding and market linkages for 'virtual startup company'. Pricing strategy.

- **Unit IV (4 Lectures)**

  Knowledge centers e.g., in universities, innovation centres, research institutions (public & private) and business incubators; R&D for technology development and upgradation; assessment of technology development; managing technology transfer;

Suggested Reading

- Adams, D.J. and Sparrow, J.C. 2008. *Enterprise for Life Scientists: Developing Innovation and Entrepreneurship in the Biosciences*. Bloxham: Scion.
- Shimasaki, C.D. 2014. *Biotechnology Entrepreneurship: Starting, Managing, and Leading Biotech Companies*. Amsterdam: Elsevier. Academic Press is an imprint of Elsevier.
- Onetti, A., and Zucchella, A. 2014. *Business Modeling for Life Science and Biotech Companies: Creating Value and Competitive Advantage with the Milestone Bridge*. Routledge.
- Jordan, J. F. 2014. *Innovation, Commercialization, and Start-Ups in Life Sciences*. London: CRC Press.
- Desai, V. 2009. *The Dynamics of Entrepreneurial Development and Management.* New Delhi: Himalaya Pub. House.

I. **Course Title : Stress Biology and Genomics**

II. **Course Code : MBB 517**

III. **Credit Hours : 2+0**

IV. **Aim of the course**

To provide advanced knowledge on genomics with reference to abiotic stress tolerance and biotic stress resistance in plants tolerance.

V. **Theory**

- **Unit I (10 Lectures)**

  Different kinds of stresses (biotic and abiotic) and adaptation strategies: Plant cell as a sensor of environmental changes; role of cell membranes in signal perception; Ways of signal transduction in cells and whole plants as a response to external factors. Abiotic stresses affecting plant productivity – Drought, salinity, water logging, temperature stresses, light stress and nutrient stress; Drought stress – Effects on plant growth and development; Components of drought resistance; Physiological, biochemical and molecular basis of tolerance mechanisms; Biotic stress (insect and pathogen) resistance mechanism.

- **Unit II (12 Lectures)**

  Strategies to manipulate drought tolerance – Osmotic adjustment and Osmoprotectants - synthesis of proline, glycine betaine, poly amines and sugars; ROS and antioxidants; hormonal metabolism - ABA signaling; signaling components – transcription factors. Water logging stress – effects on plant growth and metabolism; adaptation to water logging, tolerance mechanisms - hormones and flooding tolerance. Strategies for improving submergence tolerance. Salinity stress - effects on physiology and metabolism of plants, SOS pathways and ion homeostasis,Strategies to improve salinity tolerance in plants. Water logging stress - effects on plant growth and metabolism; tolerance mechanisms. Physiological and biochemical changes – High & Low temperature tolerance mechanisms - molecular basis of thermo tolerance. Morphological and physiological changes in plants due to high and low light stresses - photo oxidation -plastid development. Characters of heliophytes and sciophytes – solar tracking – sieve effect and light channeling. Heavy metal stress – Al and Cd stress - effects on plant growth and development, biotech Strategies to overcome heavy metal stress Nutrient stress effects on plant growth and development. Genetic manipulation strategies to overcome the stress effects.

- **Unit III (10 Lectures)**

  Genomics; transcriptomes, small RNAs and epigenomes; functional genomics; transfer of tolerance/resistant genes to model plants and validation of gene function. Different techniques for the functional validation of genes. Signalling pathway related to defense gene expression, R proteins, RNAi approach and genes from pathogens and other sources, coat protein genes, detoxification genes, transgenic and disease management. Bt proteins, resistance management strategies in transgenic crops, ecological impact of field release of transgenic crops. Bioinformatics approaches to determine gene function and network in model plants under stress.

Suggested Reading

- Buchanan, B.B., Gruissem, W. and Jones R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley and Blackwell Publications.
- Sarwat, M., Ahmad, A., Abdin, M.Z. 2013. *Stress Signaling in Plants: Genomics and Proteomics Perspective*, Volume 1, Springer.
- Heribert Hirt. 2010. *Plant Stress Biology: From Genomics to Systems Biology*, John Wiley.
- Pandey, G.K. 2015. *Elucidation of Abiotic Stress Signaling in Plants*, Stringer.

I. **Course Title** : **Gene Regulation**

II. **Course Code** : **MBB 518**

III. **Credit Hours** : **2+0**

IV. **Aim of the course**

To understand the basics of gene regulation including a wide range of mechanisms that are used by organisms to increase or decrease the production of specific gene products in terms of time, space, conditions or their combinations.

V. **Theory**

- **Unit I (8 Lectures)**

  Transcriptional regulation – Regulatory proteins, Activators and Repressors, Binding of RNA polymerase, Allosteric regulation, DNA looping, Cooperative binding, Antitermination, Combinatorial control – Regulation of *lac*, *trp* and *ara* Operons. Gene regulation in Lambda phage – lytic or lysogenic establishment.

- **Unit II (10 Lectures)**

  Regulatory sequences – Promoters, Enhancers, Silencers, Insulators, Locus Control Region. Activator proteins and their binding sites, DNA binding domain – Homeodomain, Zinc containing proteins, Leucine Zipper Motif, Helix-Loop-Helix, HMG proteins. Recruitment of RNA polymerase to promoter region, Nucleosomes and their modifiers. Signal integration. Signal transduction and transcriptional regulation. Gene Silencing. Epigenetic gene regulation.

- **Unit III (10 Lectures)**

  - Regulation by RNA in prokaryotes and eukaryotes, RNA as defense agents. Riboswitches.
  - Gene Silencing by RNA - siRNA & miRNA – synthesis and function. Noncoding RNAs their impact, categories and role in gene regulation, chromatin
  - assembly etc.

- **Unit IV (4 Lectures)**

  Negative auto-regulation, Positive auto-regulation, Bistable and Bimodal switch, Oscillating pattern of gene expression.

Suggested Reading

- Nelson, D. L. and Cox, M. M. 2017. *Lehinger's Principles of Biochemistry*, 7th edition, W H Freeman Publication New York
- Krebs, J. E., Goldstein, E. S., Kilpatrick, S. T. 2017. *Lewin's Genes* XII 12th edition, Jones & Bartlett Learning publisher, Inc
- Watson, J. D., Baker, T. A., Bell, S. P., Gann, A., Levine,M., & Lonick, R. 2014. *Molecular Biology of the Gene*, 7th Edition, Cold Spring Harbor Laboratory Press, New York.
- Gardner, E. J., Simmons MJ and Snustad, D.P. 2006. *Principles of Genetics* (2006) eighth Edition. Wiley.

Course Title with Credit Load for Ph.D. in Molecular Biology and Biotechnology

Course Code	Course Title	Credit Hours
MBB 601	**Major: 12 credits (6 credits of core + 6 credits of optional)** Plant Molecular Biology*	3+0
MBB 602	Plant Genome Engineering*	3+0
MBB 603	Plant Omics and Molecular Breeding	3+0
MBB 604	Commercial Plant Tissue Culture	2+0
MBB 605	Plant Microbe interaction#	2+0
MBB 606	RNA Biology#	1+0
MBB 607	Plant Hormones and Signaling#	2+0
MBB 608	Computational and Statistical tools in Biotechnology # Any other appropriate 500 series courses	2+1
	Minor (6 credits) from any of the following disciplines Biochemistry Genetics and Plant Breeding Microbiology Plant Physiology Plant Pathology Entomology Bioinformatics Plant Genetic Resources Any other related discipline	
	Supporting (5 credits) from the following disciplines Biochemistry Genetics and Plant Breeding Microbiology Bioinformatics Computer Applications Statistics	
MBB 691	Doctoral Seminar I	0+1
MBB 692	Doctoral Seminar II	0+1
MBB 699	Doctoral Research	0+75
	Total	**100**

I. **Course Title** : **Plant Molecular Biology**
II. **Course Code** : **MBB 601**
III. **Credit Hours** : **3+0**

IV. **Aim of the course**

- To d case studies and success stories in agriculture and industry

V. **Theory**

- **Unit I (10 Lectures)**

Model Systems in Plant Biology (Arabidopsis, Rice, etc.) Forward and Reverse Genetic Approaches. Organization expression and interaction of nuclear, Mitochondrial and Chloroplast Genomes. Cytoplasmic male sterility.

- **Unit II (12 Lectures)**

Transcriptional and Post-transcriptional Regulation of Gene Expression, Isolation of promoters and other regulatory elements, RNA interference, Transcriptional Gene Silencing, Transcript and Protein Analysis.

- **Unit III (12 Lectures)**

Plant Developmental Processes, ABC Model of Floral Development, Role of hormones (Ethylene, Cytokinin, Auxin and ABA, SA and JA) in plant development. Regulation of Flowering, Plant photoreceptors and light signal transduction, vernalization, Circadian Rhythms.

- **Unit IV (14 Lectures)**

Abiotic Stress Responses: Salt, Cold, Heat and Drought. Biotic Stress Responses. Molecular Biology of Plant-pathogen Interactions, Molecular Biology of *Rhizobium* and *Agrobacterium*- Plant interaction. Role of programmed Cell Death in Development and Defense.

Suggested Reading

- Buchanan, B.B., Gruissem, W. and Jones R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley and Blackwell Publications.
- Slater, A., Scott, N.W., and Fowler, M.R. 2003. *The Genetic Manipulation of Plants*. *Plant Biotechnology Oxford, England: Oxford University Press*.
- Walker, J.M., Rapley, R. 2008. *Plant Biotechnology and Genetics: Principles, Techniques and Applications*.

I. **Course Title** : **Plant Genome Engineering**
II. **Course Code** : **MBB 602**
III. **Credit Hours** : **3+0**

IV. **Aim of the course**

- To discuss the specialized topics and advances in field of genetic engineering and application of molecular tools in breeding of specific crops.

V. **Theory**

- **Unit I (14 Lectures)**

Conventional versus non-conventional methods for crop improvement; Present status and recent developments on the available molecular marker, transformation and genomic tools for crop improvement. Genetic engineering for resistance against abiotic (drought, salinity, flooding, temperature, etc) and biotic (insect pests, fungal, viral and bacterial diseases, weeds, etc) stresses; Genetic Engineering for increasing crop productivity by manipulation of photosynthesis, nitrogen fixation and nutrient uptake efficiency; Genetic engineering for quality improvement (protein, essential amino acids, vitamins, mineral nutrients, etc.); edible vaccines, etc.

- **Unit II (12 Lectures)**

  Recent developments in plant transformation strategies; Role of antisense and RNAi-based gene silencing in crop improvement; Regulated and tissue-specific expression of transgenes for crop improvement;

- **Unit III (12 Lectures)**

  Gene stacking; Pathway engineering; Marker-free transgenic development strategies; Genome editing: principles and methods, Development of genome-edited plants; High throughput phenotyping of transgenic plants.

- **Unit IV (10 Lectures)**

  Field studies with transgenic crops; Environmental issues associated with transgenic crops; Food and feed safety issues associated with transgenic crops; Risk assessment of transgenic food crops.

Suggested Reading

- Christou P and Klee H. 2004. *Handbook of Plant Biotechnology*. John Wiley & Sons.
- Stewart Jr, C.N. 2016. *Plant Biotechnology and Genetics: Principles, Techniques, and Applications*. John Wiley & Sons.
- Kirakosyan A and Kaufman PB. 2009. *Recent Advances in Plant Biotechnology* p. 409. Dordrecht: Springer.

I. **Course Code : MBB 603**

II. **Course Title : Plant Omics and Molecular Breeding**

III. **Credit Hours : 3+0**

IV. **Aim of the course**

- To discuss the specialized topics and advances in field of genomics and genomics assisted molecular breeding.

V. **Theory**

- **Unit I (12 Lectures)**

  Complex traits and genetic architecture, Mapping genes and QTLs, statistical concepts in QTL mapping, high-throughput genotyping using automated platforms, genetic and physical mapping of genomes, study of population structure and kinship, association genetic analysis of QTL, case studies on QTL mapping using different approaches, map-based of cloning genes and QTLs – case studies.

- **Unit II (12 Lectures)**

  Marker Assisted Breeding (MAB): Principles and methods, marker assisted foreground and background selection, marker assisted recurrent selection, whole genome selection, case studies in MAS, requirement for successful marker assisted breeding, cost of MAB.

- **Unit III (12 Lectures)**

  Concepts and methods of next generation sequencing (NGS), assembly and annotation of NGS data, genome resequencing, DNA sequence comparison, annotation and gene prediction. Genome-wide insertion mutagenesis and its use in functional genomics, transcriptome profiling using microarrays and deep sequencing, study of methylome and its significance, proteome analysis using mass spectrometry, crystallography and NMR, analysis of proteome data, study of protein- protein interactions.

- **Unit IV (12 Lectures)**

  Study of the metabolome, use of 1D/2D NMR and MS in metabolome analysis, multivariate analysis and identification of metabolite as biomarkers, study of ionome using inductively coupled plasma – mass spectroscopy (ICP-MS), correlating the data from genome, transcriptome, proteome, metabolome and ionome with phenome.

Suggested Reading

- Speicher, D.W. (Ed.). 2004. *Proteome analysis: interpreting the genome*. Elsevier.
- Tomita, M. and Nishioka, T. (Eds.). 2006. *Metabolomics: the frontier of systems biology*. Springer Science and Business Media
- Horst, L. and Wenzel, G. (Eds.). 2007. *Molecular marker systems in plant breeding and crop improvement* (Vol. 55). Springer Science and Business Media.
- Stewart C.N. 2008. *Plant Biotechnology and Genetics: Principles, Techniques and Applications*.
- Singh, B.D. and Singh, A.K. 2015. *Marker-Assisted Plant Breeding: Principles and Practices.* Springer (India) Pvt. Ltd.

I. **Course Title : Commercial Plant Tissue Culture**

II. **Course Code : MBB 604**

III. **Credit Hours : 2+0**

IV. **Aim of the course**

- To provide awareness into development of commercial scale plant tissue culture units.
- To provide an insight into the commercial applications of plant tissue culture in agriculture, medicine and industry.
- To educate about biosafety, regulatory as well as entrepreneurship opportunities.

V. **Theory**

- **Unit I (8 Lectures)**

  Micro-propagation of commercially important plant species; plant multiplication, hardening, and transplantation; genetic fidelity; scaling up and cost reduction; bioreactors; synthetic seeds; management and marketing.

- **Unit II (8 Lectures)**

  Production of useful compounds via, biotransformation and secondary metabolite production: suspension cultures, immobilization, examples of chemicals being produced for use in pharmacy, medicine and industry.

- **Unit III (9 Lectures)**

  Value-addition by transformation; development, production and release of transgenic plants; patent, bio-safety, regulatory, environmental and ethical issues; management and commercialization.

- **Unit IV (7 Lectures)**

  Project planning and preparation, economics (entrepreneurship, cost profit ratio), government policies (incubators, different facilitation projects, loan opportunities). Some case studies on success stories on commercial applications of plant tissue culture. Visits to some tissue culture based commercial units/industries.

Suggested Reading

- Honda, H., Liu, C., Kobayashi, T. 2001. *Large-Scale Plant Micropropagation*. In: Zhong J.J. *et al*. (eds) *Plant Cells. Advances in Biochemical Engineering/ Biotechnology*, vol 72. Springer, Berlin, Heidelberg.
- Bhojwani SS and Razdan MK. 1986. *Plant tissue culture: theory and practice* (Vol. 5). Elsevier.

I. **Course Title : Plant Microbe Interaction**

II. **Course Code : MBB 605**

III. **Credit Hours : 2+0**

IV. **Aim of the course**

- To discuss the specialized topics and advances in field of plantmicrobe interaction for understanding their potential in enhancing crop growth and development.

V. **Theory**

- **Unit I (8 Lectures)**

  Microbial communities in the soil and atmosphere, Community dynamics and population interactions with particular reference to plant–microbe and microbe - microbe interactions leading to symbiotic, associative, endophytic and pathogenic interactions, effects of microorganisms on plants, effects of plants on microorganisms. Recognition processes and signal exchange, Molecular aspects of Plant Growth Promoting Rhizobacteria (PGPR), Symbiotic diazotrophs: Rhizobia and association with legumes. Mycorrhizal associations: Ectomycorrhizae, Endomycorrhizae with particular emphasis to AM fungi, Ectendomycorrhizae. Biocontrol agents and their action, endophytes associations

- **Unit II (8 Lectures)**

  Enzymes, toxins, pili, siderophores, secretion systems of microbes and plants determining soil health, nutrient availability and uptake defense responses in plants: pamp-triggered immunity, effector-triggered susceptibility, qualitative resistance, r genes, structure and function, effector-triggered immunity, regulation of plant cell death, plant hormones in immunity, Plant parasite interactions and its molecular basis and impact on plant functions including photosynthesis, respiration, nitrogen metabolism and translocation

- **Unit III (8 Lectures)**

  Quorum sensing in bacteria, understanding microbiome, phytobiomes, dynamics, Applied and ecological aspects of symbioses and pathogen defense, techniques to study plant microbe interaction including microbe tagging, metagenomics and use of organismal databases to identify genes involved in interactions. Industrial application of agriculturally important microbes.

- **Unit III (8 Lectures)**

  Resistance mechanisms against attack by plant pathogens, gene-for-gene interactions; induced resistance; non-host resistance. Systemic Acquired Resistance (SAR) and Induced Systemic Resistance (ISR), Plant and microbial gene expression and signal exchange, specific regulators for different interactions including transgenic plants. Recognition mechanism and signal transduction during plant – pathogen interaction

Suggested Reading

- Rangaswamy, G. Bhagyaraj. 1993. *Agricultural Microbiology*, Prentice Hall India.
- Stacey, G., and Keen, N.T. (Eds.). 1996. *Plant-microbe interactions*. Springer Science & Business Media.
- Dickinson M. 2005. *Molecular Plant Pathology*. Bios Scientific Press, Taylor and Francis group.
- Kosuge T and Nester EW. 1989. *Plant-Microbe Interactions: Molecular and Genetic Perspectives.*Vols I-IV. McGraw Hill.
- González MBR and Gonzalez-López J. (Eds.). 2013. *Beneficial plant-microbial interactions: ecology and applications*. CRC press.

I. **Course Title : RNA Biology**

II. **Course Code : MBB 606**

III. **Credit Hours : 1+0**

IV. **Aim of the course**

- To discuss the specialized topics and advances in the field of Plant RNAs, their structure and role in cellular regulation and scope for crop improvement.

V. **Theory**

- **Unit I (4 Lectures)**

  RNA structure, functional evolution: RNA structure, types of RNA and function; Genome evolution- RNA as genetic material to regulatory molecule, Non-Coding RNAs, structure, function and regulation

- **Unit II (4 Lectures)**

  RNA synthesis, processing and regulation: transcription and its regulation in prokaryotes and eukaryotes; RNA splicing and editing; Translation and its regulation in prokaryotes and eukaryotes

- **Unit III (4 Lectures)**

  Genome regulation: Prokaryotic- attenuation, ribozymes, aptamers, riboswitches, CRISPER-Cas; eukaryotic-Exon skipping, nonsense-mediated decay, RNAi, Long non-coding RNA.

- **Unit IV (4 Lectures)**

  Epigenetic regulation. RNA-based gene silencing technologies and their applications for crop improvement

Suggested Reading

- Elliott, D., and Ladomery, M. 2017. *Molecular biology of RNA*. Oxford University Press.
- Rao, M.R.S. (Ed.) 2017. *Long Non-Coding RNA Biology*, Springer,
- Donald, C.R., Hannon, G., Ares, M. and Nilsen, T.W. 2011. *RNA: A Laboratory*

Manual, CSHL Press.

- Maas, S. (Ed.). 2013. *RNA Editing: Current Research and Future Trends*. Horizon Scientific
- Press.

I. **Course Title : Plant Hormones and Signaling**

II. **Course Code : MBB 607**

III. **Credit Hours : 2+0**

IV. **Aim of the course**

- To provide in-depth knowledge of plant hormone and their role in plant growth and development.

V. **Theory**

- **Unit I (12 Lectures)**

Hormone Biosynthesis, Metabolism and its Regulation: Auxin biosynthesis and metabolism, Gibberellin biosynthesis and Inactivation, Cytokinin biosynthesis and metabolism, Ethylene biosynthesis, Abscisic acid biosynthesis and metabolism, Brassinosteroid biosynthesis and metabolism. Salicylic acid and jasmonate biosynthesis and metabolism.

- **Unit II (12 Lectures)**

Functioning of hormones in plant growth and development: Transport of Auxins, Induction of vascular tissues by Auxin, Hormones and the regulation of water balance, seed development and germination, Hormonal control of day length and senescence.

- **Unit III (12 Lectures)**

Action of Hormones: Hormones in defense against insects and disease; Role of jasmonates, salicylic acids and peptide hormones for defense, growth, development and reproduction; Methods of plant hormone analysis. NPR 1 dependent Salicylic acid signaling, PAMP and effector triggered immunity, systemic acquired resistance and SA signaling.

- **Unit IV (12 Lectures)**

Hormone Signal Transduction: Auxin metabolism, transport and signal transduction, Cytokinin types, synthesis, metabolism, transport and signal transduction, Gibberellin biosynthesis, transport, signal transduction in stem elongation & Leaf Growth, Ethylene metabolism, perception and signaling in seedling growth and development, Ethylene signal transduction in fruits and flowers, Abscisic acid metabolism, transport and signal transduction in nuclear gene expression and stomatal responses. Brassinosteroid biosynthesis, catabolism and signal transduction. Strigalactone biosynthesis, transport and signaling in plant parasitism and symbiosis. Methods of Plant Hormone Analysis**:** Quantitative analysis of plant hormones based on LC/MS.

Suggested Reading

- Davies Jr. F. *et al*. 2017. Hart Mann and KRster's. *Plant Propagation: Principles and Practices.* Pearson.

I. **Course Title : Computational and Statistical tools in Biotechnology**

II. **Course Code : MBB 608**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

- To provide information on basic principles of computational biology and statistical tools used for data analysis

V. **Theory**

- **Unit I (8 Lectures)**

  Basic molecular biology; introduction to the basic principles of structure/function analysis of biological molecules; genome analysis; different types and classification of genome databases (e.g. HTGS, DNA, Protein, EST, STS, SNPs, Unigenes, etc.)

- **Unit II (8 Lectures)**

  Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing; Resampling techniques – Bootstrapping and Jack- knifing; Markov Models. Hidden Markov Models, Bayesian estimation and Gibbs sampling

- **Unit III (8 Lectures)**

  DNA sequence retrieval system, various DNA and protein sequence file formats, Basic concepts of similarity searching and sequence alignments, pair wise and multiple sequence alignments, DNA sequence analysis, different gene prediction models and gene annotation tools

- **Unit IV (8 Lectures)**

  Protein sequence analysis and structure prediction, comparative genome analysis, phylogenetic analysis, gene expression analysis tools, programming languages and their applications in bioinformatics

Practical (16)

- Different Types of Databases and Database Search and Retrieval
- DNA and Protein Sequence Analysis
- Similarity Searching and Multiple Alignments
- Gene Annotation
- Phylogenetic Analysis
- Sequence Analysis
- Protein Structure Prediction
- Analysis of Microarray Data
- Programming Languages in Bioinformatics.

Suggested Reading

- Xiong J. 2012. *Essential Bioinformatics*, Cambridge University Press.
- Andreas, D.B., and Ouellette B.F.F., (Eds) 2004. *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* 3rd Edition, Wiley Interscience.
- Mount D. 2004. *Bioinformatics: Sequence and Genome Analysis*, 2nd Edition. By, CSHL Press.
- Augen J. 2004. *Bioinformatics in the Post-Genomic Era: Genome, Transcriptome, Proteome, and Information-Based Medicine*.
- Galperin M.Y. and Koonin E.V. (Eds) 2003. *Frontiers in Computational Genomics*.

AGRICULTURAL EXTENSION EDUCATION

Course Title with Credit Load for M.Sc. in Agricultural Extension Education

Course Code	Course Title	Credit Hours
EXT-501*	Extension Landscape	2(2+0)
EXT-502*	Applied Behaviour Change	3(2+1)
EXT-503*	Organisational Behaviour and Development	3(2+1)
EXT-504*	Research Methodology in Extension	3(2+1)
EXT-505*	Capacity Development	3(2+1)
EXT-506*	ICTs for Agricultural Extension and Advisory Services	3(2+1)
EXT-507*	Evaluation and Impact Assessment	3(2+1)
EXT-591	Master's Seminar	01
EXT-699	Thesis/Research	30
	Total	70

Minor Courses 08

EXT-508	Managing Extension Organisations	3(2+1)
EXT-509	Enabling Innovation	2(1+1)
EXT-510	Gender Mainstreaming	3(2+1)

I. **Course Title : Extension Landscape**

II. **Course Code : EXT 501**

III. **Credit Hours : 2+0**

IV. **Why this course?**

Extension and Advisory Services (EAS) need to support farmers to deal with several new challenges they face currently. To effectively support farmers, EAS should perform several new functions and it should have capacities to perform these functions. EAS have evolved considerably especially during the last 3 decades. Several new approaches have emerged and many new funding and delivery models emerged in response to reforms (economic policies and new governance structure) implemented in several countries. Apart from these, new insights from communication and innovation studies have also started to influence the practice of extension. There is a lot of interest globally in strengthening pluralistic EAS and enhancing its contribution towards development of an effective Agricultural Innovation System (AIS). Keeping these in view, there is a need to orient students of extension on how extension is shaped globally and the policy level challenges it faces so that the extension students fit well to the global demand for competent extension professionals who can appreciate and understand this changing context.

V. Aim of the course

The aim of this course is to introduce the new challenges before extension and how extension is evolving globally. It presents the new capacities that are needed by EAS providers to provide a much wider support to farmers and it orient students to the new insights from communication and innovation studies that are influencing the practice of extension globally. The course also help students to appreciate the process and the impact of extension reforms implemented in many countries, the new approaches that are evolving globally in different regions and the policy challenges in managing a pluralistic extension system.

The course is organized as follows:

No	Blocks	Units
	1. Globally, What is new in Extension? 2. Challenges Before Extension and Advisory Services 3. New Functions and New Capacities 4. Pluralism in EAS	
2.	Insights from Communication & Innovation Studies & Extension Approaches	1. Paradigm Shift from Linear to Systems New Approach 2. Evolving Extension Approaches
3	Extension Reforms And Policy Challenges	1. Changes In Governance, Funding and Delivery of EAS 2. Challenges In Managing Pluralistic EAS

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the changing global extension landscape
- Broaden their understanding on the role of EAS in agricultural innovation system
- Critically evaluate the reforms in extension and the evolving approaches in extension
- Analyse the policy level challenges in extension funding and delivery

Block 1: Globally, What Is New In Extension?

Unit 1: Challenges before Extension and Advisory Services (EAS)

Extension and Advisory Services (EAS)- Meaning (embracing pluralism and new functions) New challenges before farmers and extension professionals: Natural Resource Management-Supporting farmers to manage the declining/deteriorating water and soil for farming; Gender Mainstreaming- How extension can enhance access to new knowledge among women farmers; Nutrition- Role of extension in supporting communities with growing nutritious crop and eating healthy food; Linking farmers to markets- Value chain extension including organizing farmers, strengthen value chain and supporting farmers to respond to new standards and regulations in agri-food systems; Adaptation to climate changes-How extension can contribute to up-scaling Climate Smart Agriculture; Supporting family farms-strengthening the capacities of family farms; Migration-Advising farmers to better respond to opportunities that emerge from increasing mobility and also supporting migrants in enhancing their knowledge and skills; Attracting and Retaining Youth in Agriculture including promotion of agripreneurship and agri-tourism; Urban and peri-urban farming- How to support and address issues associated with urban and peri-urban agriculture; Farmer distress, suicides- Supporting farmers in tackling farm distress.

Unit 2: New Functions and New Capacities

Beyond transfer of technology: Performing new functions to deal with new challenges; Organising producers into groups-dealing with problems that need collective decision making such as Natural Resource Management (NRM) and access to markets; Mediating conflicts and building consensus to strengthen collective decision making; Facilitating access to credit, inputs and services-including development of service providers; Influencing policies to promote new knowledge at a scale networking and partnership development including convening multi-stakeholder platforms/ innovation platforms.

New capacities needed by extension and advisory services at different levels –at the individual (lower, middle management and senior management levels), organizational and enabling environment levels; – Core competencies at the individual level; Varied mechanisms for capacity development (beyond training).

Unit 3: Pluralism in EAS

Pluralism in Extension Delivery: Role of private sector (input firms, agri-business companies, consultant firms and individual consultants)- Trends in the development of private extension and advisory services in India and other countries; challenges faced by private extension providers; Role of Non-Governmental Organizations (National/international)/ Civil Society Organizations (CSOs) in providing extension- Experiences from India and other countries; Producer Organizations- Role in strengthening demand and supply of extension services; their strength and weaknesses-experiences from different sectors; Role of Media and ICT advisory service providers; global experiences with use of media and ICTs in advisory services provision.

Block 2: Insights From Innovation Studies and New Extension Approaches

Unit 1: Paradigm Shift from Linear to Systems Approach

Diffusion of Innovations paradigm- strengths and limitations; multiple sources of innovation-farmer innovation, institutional innovation; farmer participation in technology generation and promotion; strength and limitations; Agricultural Knowledge and Information Systems (AKIS); strength and limitations; Agricultural Innovation Systems (AIS); Redefining Innovation- Role of Extension and Advisory Services in AIS-From information delivery to intermediation across multiple nodes; Role of brokering; Innovation Platforms, Innovation Management; Strength and weaknesses of AIS. Rethinking Communication in the Innovation Process – Network building, support social learning, dealing with dynamics of power and conflict.

Unit 2: Evolving Extension Approaches

Evolution and features of extension approaches: Transfer of technology approach; educational approach, farmer participatory extension approach, demand-driven extension, market led extension (value chain extension), extension for climate smart agriculture, gender sensitive extension, extension for entrepreneurship extension systems in different regions: Asia-Pacific, Europe, Latin America, Australia, North America Networking for Strengthening EAS: GFRAS (Global Forum for Rural Advisory Services) and its regional networks.

Block 3: Extension Reforms and Policy Challenges

Unit 1: Changes in Governance, Funding and Delivery

Reduction in public funding: public withdrawal from extension provision (partial/ full); Examples/Cases; Privatization: Public funding and private delivery; cost sharing and cost recovery; Examples/Cases; Decentralisation of extension services; Examples/ Cases; Lessons from extension reforms in different countries; Extension and Sustainable Development Goals (SDGs).

Unit 2: Challenges in Managing Pluralistic Extension Systems

Pluralism: Managing pluralism and co-ordination of pluralistic extension provision; Public private partnerships in extension (including the role of local governments/panchayats and producer organisations); Examples, challenges in co-ordination;

Achieving convergence in extension planning and delivery, Financing Extension: Mobilising resources for extension: public investments, donor support (grants/loans); Monitoring and Evaluation of Extension: Generating appropriate data for assessment and evaluation of pluralistic extension; Strengthening extension policy interface; Generating evidence on impact of communication.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Book review by students
- Student presentation
- Group work

VIII. Suggested Reading

- Adolph B. 2011. *Rural Advisory Services World wide: A Synthesis of Actors and Issues. GFRAS*: Lindau, Switzerland. https://www.g-fras.org/en/knowledge/gfras-publications.html? download=6: rural-advisory-services-worldwide&start=40

- Ashok G, Sharma P, Anisha S and Prerna T. 2018. *Agriculture Extension System in India Review of Current Status, Trends and the Way Forward.* Indian Council for Research on International Economic Relations (ICRIER). http://icrier.org/pdf/Agriculture-Extension- System-in-India-2018.pdf
- Barber J, Mangnus E and Bitzer V. 2016. *Harnessing ICT for agricultural extension***.** KIT Working Paper 2016: 4. https://213ou636sh0ptphd141fqei1-wpengine.netdna-ssl.com/sed/wp-content/uploads/sites/2/2016/11/KIT_WP 2016-4_Harnessing-ICT-for-agricultural-extension.pdf
- Bentley J, Chowdhury A and David S. 2015. *Videos for Agricultural Extension.* Note 6. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://www.g-fras.org/en/good-practice-notes/6-video-for-agricultural-extension.html #SNote1
- Bingen RJ and Simpson BM. 2015. *Farmer Organizations and Modernizing Extension and Advisory Services*. MEAS Discussion Paper. http://meas.illinois.edu/wp-content/uploads/ 2015/04/Bingen-Simpson-2014-FarmerOrganizations-MEAS-Discussion-Paper.pdf
- Bitzer V, Wennink B and de Steenhuijsen PB. 2016. *The governance of agricultural extension systems*. KIT Working Paper 2016: 1.http://213ou636sh0ptphd141fqei1.wpengine.netdna-cdn.com/sed/wpcontent/uploads/sites/2/2016/03/WPS_1-2016-web.pdf
- Bitzer V, Wongtschowski M, Hani M and Blum M. 2016. *New directions for inclusive Pluralistic Service Systems.* In New Directions for Inclusive Pluralistic Service Systems Rome (Italy). FAO. http://www.fao.org/3/a-i6104e.pdf.
- Burton ES & Kristin D. 2014. *Status of Agricultural Extension and Rural Advisory Services Worldwide.* GFRAS: Lindau, Switzerland. http://www.g-fras.org/en/knowledge/gfras-publications.html?download=391: status-of-agricultural-extension-and-rural-advisory- services-worldwide
- Christoplos I. 2010. *Mobilizing the potential of rural and agricultural extension*. Food and Agriculture Organization of the United Nations. Rome. http://www.fao.org/docrep/012/ i1444e/i1444e.pdf
- Colverson KE. 2015. *Integrating Gender into Rural Advisory Services.* Note 4. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://www.g-fras.org/en/good-practice-notes/integrating-gender-into-rural-advisory-services.html#SNote1
- David S. 2018. *Migration and rural advisory services.* GFRAS Issues Paper 2. Global Forum for Rural Advisory Services. https://www.g-fras.org/en/knowledge/gfras-publications/category/ 97-gfras-issues-papers.html?download=856: migration-and-rural-advisory-services
- Davis K and Heemskerk W. 2012. *Coordination and Collective Action for Agricultural Innovation* Overview Module 1 Investment in Extension and Advisory Services as Part of Agricultural Innovation Systems. In

Agricultural Innovation Systems: An Investment Sourcebook. Agricultural and Rural Development. World Bank. © World Bank.

- http://siteresources.worldbank.org/INTARD/Resources/335807-1330620492317/ 9780821386842ch3.pdf
- FAO. 2016. *New directions for inclusive Pluralistic Service Systems*. Report of FAO Expert Consultation. Food and Agriculture Organization of the United Nations and Royal Tropical Institute, Rome. http://www.fao.org/3/ai6103e.pdf
- FAO.2017. *Climate-Smart Agriculture Sourcebook.* Available at: http://www.fao.org/3/a- i3325e.pdf
- Faure G, Pautrizel L, de Romémont A, Toillier A, Odru M and Havard M. 2015. *Management Advice for Family Farms to Strengthen Entrepreneurial Skills***.** Note 8. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://www.g-fras.org/en/good-practice-notes/management-advice-for-family-farms-to-strengthen- entrepreneurial-skills.html#SNote8
- Francis J, Mytelka L, Van Huis A and Röling N (eds.). 2016. *Innovation Systems: TowardsEffective Strategies in support of Smallholder Farmers.* Technical Centre for Agricultural and Rural Cooperation (CTA) and Wageningen University and Research (WUR)/ Convergence of Sciences Strengthening Innovation Systems (CoS-SIS), Wageningen. https:/
- /publications.cta.int/media/publications/downloads/1829_PDF.pdf
- GFRAS. 2012. *Building Knowledge Systems in Agriculture Five Key Areas for Mobilising the Potential of Extension and Advisory Services.* Global Forum for Rural Advisory Services. http://www. fao.org/uploads/media/1_gfras_positionpaper_final2_websmallpdf% 20com%20(1).pdf
- GFRAS. 2015. *Producer organisations in rural advisory services: Evidence and experiences.* Position Paper. Lindau: Global Forum for Rural Advisory Services. http://www.g-fras.org/ en/593-producer-organisations-in-rural-advisory-servicesevidence-and-experiences.html
- GFRAS. 2016. *Five Key Areas for Mobilising the Potential of Rural Advisory Services.* GFRAS Brief 1. Global Forum for Rural Advisory Services. https://www.g-fras.org/en/knowledge/ gfras-publications.html?download=4: five-key-areas-for-mobilising-the-potential-of-rural- advisory-services.
- GFRAS.2016. *The New Extensionist Learning Kit*. http://g-fras.org/en/knowledge/new- extensionist-learningkit-nelk.html#module-1-introduction-to-the-new-extensionist
- GRFAS. 2014. *Policy Compendium.* http://www.g-fras.org/en/policy-compendium.html
- Gwyn EJ and Garforth C. nd. *The history, development, and future of agricultural extension.*
- FAO. Rome. http://www.fao.org/docrep/W5830E/w5830e03.htm
- Jennings JR, Packham RG and Woodside D. 2011. *Shaping change: natural resource management, agriculture and the role of extension.*

Australasia Pacific Extension Network. http://www.apen.org.au/shaping-change

- Leeuwis C with A W van den Ban. 2004. *Communication for rural innovation: Rethinking agricultural extension.* John Wiley & Sons.
- Magdalena Blum and Sanne Chipeta. 2016. *Innovative Financing Mechanisms for Demand- driven Agricultural Advisory Services.* Gfras good practice note for extension and advisory services 21. Global Forum for Rural Advisory Services. https://www.g-fras.org/en/good- practice-notes/20-innovative-financing-mechanisms.html#SNote8
- Manfre C, Rubin D and Nordehn C. 2017. *Assessing How Agricultural Technologies can Change Gender Dynamics and Food Security Outcomes.* A three part toolkit. Integrating Gender and Nutrition within Agricultural Extension Services (INGENAES). http://www.culturalpractice.com/wp-content/uploads/Introduction-to-the-Toolkit-Final-10_17.pdf
- Mittal N, Sulaiman RV and Prasad RM. 2016. *Assessing capacity needs of Extension and Advisory Services: A Guide for Facilitators.* Agricultural Extension in South Asia (AESA). http://crispindia.org/wpcontent/uploads/2015/09/Facilitators-Guide-Final-LR.pdf
- Posthumus H and Wongtschowski M. 2014. *Innovation Platforms.* Note 1. GFRAS good practice note for extension and advisory services. GFRAS: Lindau, Switzerland. https://www.g- fras.org/en/good-practice-notes/innovation-platforms.html#SNote1
- Rajalahti R, Janssen W and Pehu E. 2008. *Agricultural innovation systems: From diagnostics toward operational practices.* Agriculture & Rural Development Department, World Bank. https://agrilinks.org/sites/default/files/resource/files/ARDDiscussionPaper38.pdf
- Rao S. 2015. *Using Radio in Agricultural Extension.* Note 18. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://www.g-fras.org/ en/good-practice-notes/using-radio-in-agricultural-extension.html#SNote8
- Rivera W and Zijp W. 2002. *Contracting for Agricultural Extension-International Case Studies and Emerging Practices.* CABI Publishing.
- Saravanan R and Suchiradipta B. 2015. *mExtension – Mobile Phones for Agricultural Advisory Services.* Note 17. Gfras good practice note for extension and advisory services. GFRAS: Lindau, Switzerland.
- https://www.g-fras.org/en/good-practice-notes/mextension.html#SNote17
- Saravanan R, Suchiradipta B, Meera SN, Kathiresan C and Anandaraja N. 2015. *Web Portals for Agricultural Extension and Advisory Services.* Note 16. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://www.g-fras.org/en/good-practice-notes/16-web-portals-for-agricultural-extension-and-advisory- services.html#SNote8
- Saravanan R, Sulaiman RV, Davis K and Suchiradipta B. 2015. *Navigating ICTs for Extension and Advisory Services.* Note 11. GFRAS

Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://agrilinks.org/sites/default/files/resource/files/gfras-ggp-note11_navigating_icts_for_ras_1.pdf

- Sulaiman RV 2015. *Agricultural Innovation Systems.* Note 13. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. https://www.g-fras.org/ en/good-practice-notes/agricultural-innovation-systems.html#SNote8
- Sulaiman RV and Davis K. 2012. *The New Extensionist: Roles, strategies, and capacities to strengthen extension and advisory services.* In Lindau, Switzerland: Global Forum for Rural Advisory Services. http://www.g-fras.org/en/157-thenew-extensionist
- Suvedi M and Kaplowitz MD. 2016. *What Every Extension Worker Should Know: Core Competency Handbook.* Michigan State University. Department of Community Sustainability. https://agrilinks.org/library/what-every-extensionworker-should-know-core- competency-handbook
- Swanson BE and Rajalahti R. 2010. *Strengthening Agricultural Extension and Advisory Systems: Procedures for Assessing. Transforming, and Evaluating Extension Systems.* Agriculture and Rural Development Discussion Paper; No. 45. World Bank, Washington, DC. © World Bank. http://siteresources.worldbank.org/INTARD/Resources/Stren_combined_web.pdf
- Swanson BE. 2008. *Global Review of Good Agricultural Extension and Advisory Service Practices.* Food and Agriculture Organization of the United Nations. Rome. http://www.fao.org/docrep/pdf/011/i0261e/i0261e00.pdf
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- https://www.g-fras.org/en/good-practice-notes/27-professionalisation.html#SNote27 World Bank. 2006. *Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of*
- *Research Systems.* Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/7184

Websites

- **AESA-** Agricultural Extension in South Asia http://www.aesanetwork.org/
- **FAO-** Food and Agricultural Organisation (Research and Extension) http://www.fao.org/ research-and-extension/en/
- **GFRAS-** Global Forum for Rural Advisory Services http://www.g-fras.org/en/
- **INGENEAS-** Integrating Gender and Nutrition within Agricultural Extension Services https://ingenaes.illinois.edu/
- **IFPRI-** International Food Policy Research Institute (Extension) http://www.ifpri.org/topic/ agricultural-extension
- **KIT-** Royal Tropical Institute (KIT)-Sustainable Economic Development https://www.kit.nl/sed/

- **WUR-** Wageningen University and Research Research (Knowledge, Technology and Innovation Group (KTI)) https://www.wur.nl/en/Research-Results/Chair-groups/Social-Sciences/ KnowledgeTechnology-and-Innovation-Group.htm

I. **Course Title : Applied Behavioural Science**

II. **Course Code : EXT 502**

III. **Credit Hours : 2+1**

IV. **Why this course?**

The behavioural change of the stakeholders is the key objective in extension profession, which is reflected through their enhanced capacity, attitude change, modification of perceptions and beliefs, improved understanding of a system, adoption of improved technologies, empowerment and resilience to adverse phenomenon and improved decision-making. Irrespective of their role and profession, all the key stakeholders in agriculture like farmers, extension agents, scientists/ academicians, development managers and policy makers are human beings, whose behaviour is the product of internal psychological processes influenced by external environment. Since human behaviour is a psychological phenomenon, expressed through interaction of internal psychological processes, social systems and external environment, there is an essential need to understand how these psychological processes guide the behavioural change. These psychological processes may be expressed at individual, group, community and organisational level involving human learning, choices, judgement and decisions about an extension intervention.

V. **Aim of the course**

This course aims to build capacities of students to understand the fundamental psychological processes which guide human behaviour at individual, group and community levels in specific contexts, to develop sound extension strategies.

The course is organized as follows:

No	Blocks	Units
1	Foundations of Behaviour Change	1. Foundations of Human Behaviour
2	Cognitive Processes and Learning affecting Human	1.CognitiveProcesses Behaviour 2. Information Processing 3. Learning 4. Judgement, Choice and Decision-making
3	Human Behaviour in the Society Influence	1. Attitudes and 2. Social Judgement, Social Identity and Inter-Group Relations

VI. Theory

Block 1: Foundations of Behaviour Change

Unit 1: Foundations of Human Behaviour

Human behaviour – Meaning, importance and factors influencing human behaviour; Biological bases of human behaviour – Nervous system, brain, endocrine system and genes; Individual variations – intelligence, ability and creativity– foundations and theories, personality and temperament - foundations, approaches, theories of personality, measuring personality (traits, locus of control, self-efficacy; Personal, social and moral development – meaning, concepts – self-concept, self-esteem and self-worth and theories. Motivation – foundations, approaches, theories, managing human needs and motivations; perceiving others – impression, attitude, opinions; Emotions - foundations, types and functions, measuring emotional intelligence.

Block 2: Cognitive Processes and Learning

Unit 1: Cognitive Processes Affecting Human Behaviour

Sensory organs and their role cognition; Cognitive processes – Attention, perception, remembering and forgetting, knowledge and *e*xpertise – foundations and theories; Principles and processes of perception; Consciousness – meaning, types, sleep and dreams; Learning and Memory – Memory - meaning, types and mechanisms of storage and retrieval of memories in the Human brain; Complex cognitive processes - Concept formation, Thinking, Problem solving and transfer – foundations, theories and approaches.

Unit 2: Information Processing

Information processing – meaning, principles; Models of information processing - Waugh and Norman model of primary and secondary memory; Atkinson and Shiffrin's stage model of memory; other models including blooms taxonomy and Sternberg's Information Processing Approach; Attention and perception – meaning, types, theories and models; Consciousness.

Unit 3: Learning

Learning – foundations, approaches and theories; Cognitive approaches of learning – meaning, principles theories and models; Memory – foundations, types; Behavioural approaches of learning – foundations and theories - classical conditioning, operant conditioning, applied behaviour analysis; Strategies for behavioural changes, behavioural change with effective positive reinforcement, teaching new behaviour - Social cognitive and constructivist approaches to learning – foundations and theories – social cognitive theory, Self- regulated learning; learning styles – meaning, types and applications in learning.

Unit 4: Judgement, Choice and Decision-making

Human judgement – meaning, nature, randomness of situations, theories and models; Choice – meaning, criteria for evaluating options; theories and models of human choice; Choice architecture; Decision-making – Meaning, problem analysis; steps and techniques of decision-making under different contexts.

Block 3: Human Behaviour in the Society

Unit 1: Attitudes and Influence

Attitudes - meaning, assumptions, types, theories and models of attitude formation; methods of changing attitudes, Relating to others - liking, attraction, helping behaviour, prejudice, discrimination and aggression; Liking/ affect – meaning, types and theories; Attraction – meaning, types and theories; Persuasion – meaning, theories and techniques; Social influence and groups – conformity, compliance and obedience.

Unit 2: Social Judgement, Social Identity and Inter-Group Relations

Social judgement – meaning, frame of reference, stereotyping; The judgement of attitude models; Attribution – meaning, theories; Rational decision making; Social identify – meaning, types; assessment; Groups – meaning, types, group processes; sustainability of groups; Inter group processes and theories social learning.

VII. Practicals

- Understanding perception – Attentional Blink and Repetition Blindness Exercises
- Understanding attention - Testing selective attention capacity and skills and processing speed ability through Stroop test
- Hands-on experience in the techniques for assessing creative thinking – divergent and convergent thinking
- Lab exercises in applying Maslow's need hierarchy to assess motivation
- Learning - Classical conditioning and operant conditioning
- Assessing learning styles through Barsch and Kolb inventories
- Practical experience in building self-esteem
- Assessment of emotional intelligence
- Exercises in problem solving
- Exercises in visual perception
- Measuring self-concept using psychometric tools
- Experiment on factors influencing information processing
- Assessment of attitudes
- Hands on experience in methods of persuasion
- Field experience in assessing social judgement
- Simulation exercises to understand decision-making under different situations
- Exercises in rational decision-making.
- Practical exercise on behavioural change

Teaching methods/activities

- Lecture cum discussion
- Class exercises
- Group presentation

Learning outcome

The students should:

- Understand the biological and cognitive processes determining human behaviour
- Understand the process of learning under different context
- Develop competencies in influencing the human decision process in various contexts
- Design effective strategies to influence attitude and behaviour

Suggested Reading

- Eiser J, Richard. 2011. *Social Psychology: Attitudes, Cognition and Social Behaviour*. Cambridge: Cambridge University Press.(First Edition, 1986))
- Eysenck MW and Keane M T. 2010. *Cognitive psychology: A student's handbook.* Sixth Edition, Hove: Psychology Press.
- Feldman RS. 2008. *Essentials of understanding psychology* (7th ed.). Boston: McGraw-Hill. Gilovich T, Keltner D, and Nisbett RE. 2011. *Social psychology*. New York: W.W. Norton & Co. Moreno R. 2010. *Educational Psychology*. Hoboken, NJ: John Wiley & Sons Inc.
- Nevid JS. 2012. *Essentials of psychology: Concepts and applications* Belmont, CA: Wadsworth, Cengage Learning.
- Rachlin H. 1989. *Judgment, decision, and choice: A cognitive/behavioral synthesis.* New York: W.H. Freeman.

I. **Course Title : Organisational Behavior and Development**

II. **Course Code : EXT 503**

III. **Credit Hours : 2+1**

IV. **Why this course?**

In changing and competitive world, the survival of any organization is dependent on its ability to adjust to the new challenges, adapt its structure and develop the competencies needed among its staff. This course is designed to understand the theory and practice relating to the processes of organizational behavior, development and change. It attempts to bring about change in the different levels of the organization (the individual, group and organization) using a wide variety of interventions.

V. **Aim of the course**

- To understand the theory and practice relating to the processes of organizational behavior, development and change.
- To develop insight and competence in diagnostic and intervention processes and skills for initiating and facilitating change in organizations.
- To gain necessary self-insight, skills in facilitation, organizational development (OD) skills, group process and techniques, to become an effective change agents and OD consultants.

- To understand the behavior of individuals and small groups in organization with special focus on beliefs, attitudes and values, human inference - attribution, self- concept, motivation, active listening, interpersonal communication, conflicts management.

The course is organized as follows:

No	Blocks	Units
1.	Organisational Behaviour	1. Basics of Organisation 2. Basics of Organisational Behaviour 3. Individual Behaviour in Organizations 4. Group Behaviour in Organizations 5. Productive Behaviour and Occupational Stress 6. Organisational Systems
2.	Organisational Development Development	1. Overview of Organisational 2. Managing the Organisational Development Process 3. Organisational Development Interventions 4. Organisational Development Practitioner or Consultant

VI. Theory

Block 1: Organizational Behavior

Unit 1: Basics of Organization

Introduction to organizations-concept and characteristics of organizations; Typology of organizations; Theories of organizations: nature of organizational theory, Classical theories, Modern management theories, System Theory - criticisms and lessons learnt/ analysis.

Unit 2: Basics of Organizational Behaviour

Concepts of Organisational Behaviour, Scope, Importance, Models of OB.

Unit 3: Individual Behaviour in Organizations

Introduction, Self-awareness, Perception and Attribution, Learning, Systems approach to studying organization needs and motives – attitude, values and ethical behavior, Personality, Motivation-Concept & Theories, Managing motivation in organizations.

Unit 4: Group Behaviour in Organization

Foundations of group, group behaviour and group dynamics, Group development and cohesiveness, Group performance and decision making, Intergroup relations; Teams in Organizations-Team building experiential exercises, Interpersonal communication and group; Leadership: Meaning, types, Theories and Perspectives on effective leadership, Power and

Influence, managing conflict and negotiation skills, Job/stress management, decision-making, problem-solving techniques.

Unit 5: Productive Behaviour and Occupational Stress

Productive behaviour - Meaning, dimension; Job analysis and Job performance – meaning, dimensions, determinants and measurement; Job satisfaction and organizational commitment - meaning, dimensions and measures roles and role clarity; Occupational stress – meaning, sources, theories and models, effects, coping mechanism, effects and management; Occupational stress in farming, farmer groups/ organizations, research and extension organizations.

Unit 6: Organizational System

Organizations Structure- Need and types, line & staff, functional, committee, project structure organizations, centralization & decentralization, different stages of growth and designing the organizational structure; Organizational Design- Parameters of organizational design, organization and environment, organizational strategy, organization and technology, power and conflicts in Organizations, Organizational Decision-Making; Organizational Culture vs climate; organizational change; organizational learning and transformation.

Block 2: Organisational Development

Unit 1: Overview of Organizational Development

Concept of OD, Importance and Characteristics, Objectives of OD, History and Evolution of OD, Implications of OD Values.

Unit 2: Managing the Organizational Development Process

Basic Component of OD Program-Diagnosis-contracting and diagnosing the problem, diagnostic models, open systems, individual level group level and organizational level diagnosis; Action-collection and analysis for diagnostic information, feeding back the diagnosed information and interventions; Program management- entering OD relationship, contracting, diagnosis, feedback, planned change, intervention, evaluation.

Unit 3: Organizational Development Interventions

Meaning, Importance, Characteristics of organization development interventions, Classification of OD interventions-interpersonal interventions, Team interventions, Structural interventions, Comprehensive interventions.

Unit 4: Organizational Development Practitioner or Consultant

Who is OD consultant? Types of OD consultants and their advantages, qualifications, Comparison of traditional consultants Vs. OD consultants, Organizational development process by the practitioners skills and activities.

VII. Practicals

- Case analysis of organization in terms of process – attitudes and values, motivation, leadership.
- Simulation exercises on problem-solving – study of organizational climate in different organizations.

- Study of organizational structure of development departments, study of departmentalization, span of control, delegation of authority, decision-making patterns.
- Study of individual and group behaviour at work in an organization.
- Conflicts and their management in an organization.
- Comparative study of functional and non-functional organizations and drawing factors for organizational effectiveness.
- Exercises on OD interventions (Interpersonal, Team, Structural, Comprehensive) with its procedure to conduct in an organization
- Skills required for an OD

VIII. Teaching methods/activities

- Lecture cum discussion
- Cases
- Class exercises
- Group presentation

IX. Learning outcome

This course will equip the students to become potential change agents and OD practitioners. They should be able to learn how to improve individual, group/team and organizational performance through the use of OD techniques or interventions.

X. Suggested Reading

- Bhattacharyya DK. 2011. *Organizational Change and Development*, Oxford University Press. Hellriegel D, Sloccum JW and Woodman. 2001. **Organizational Behaviour.** Cincinnati, Ohio: South-Western College Pub.
- Luthans F. 2002. *Organizational Behaviour*. Tata McGraw-Hill, New York
- Newstrom JW and Davis K. 2002. *Organizational Behaviour: Human behaviour at Work*. Tata- McGraw Hill, New Delhi.
- Peter MS. 1998. *The Fifth Discipline: The Art and Practice of Learning Organization*. Random House, London.
- Pradip NK. 1992. *Organizational Designs for Excellence*. Tata McGraw Hill, New Delhi. Shukla, Madhukar. 1996. *Understanding Organizations*. Prentice Hall of India, New Delhi. Stephens PR and Timothy AJ. 2006. *Organizational Behaviour*, 12th Edition. Prentice Hall Pub.
- Thomas GC and Christopher GW. 2013. *Organizational development and change*, 10th edition, South-Western college publishing.
- Wendell LF and Cecil HB. 1999. *Organizational Development: Behavioural science interventions for organization improvement*, Pearson. 368 pp.

I. Course Title : Research Methodology in Extension

II. Course Code : EXT 504

III. Credit Hours : 2+1

IV. Why this course?

Growth of any discipline is directly proportional to the creation of knowledge in that discipline. Extension research is the backbone of extension discipline. Extension research is a unique social science inquiry where research ideas are gathered from the field problems and put through a systematic cycle of objective investigations that result in significant solutions. Apart from developing theories and models that advance scientific knowledge, extension research should also provide new insights for improving extension policy and practice. As extension is a field oriented discipline seeking to improve the welfare of its stakeholders, the extension professionals require critical competencies in conducting empirical research for developing sound extension models, methods and tools.

V. Aim of the course

This course aimed to create a workforce which has sound fundamental knowledge and critical competencies in planning, conducting and applying behavioural research for developing quality extension models, methods and tools.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to behavioural research	1. Nature of Behavioural Research 2. Role of Behavioural Research in Extension
2.	Steps in behavioural research process	1. Formulating a Research Problem 2. Reviewing the Literature 3. Identifying Variables and Hypotheses 4. Formulating Research Designs, Methods and Tools 5. Selecting Sample 6. Collecting Data 7. Analysing and Interpreting the Data 8. Reporting and Evaluating Research

VI. Theory

Block 1: Introduction to Behavioural Research

Unit 1:

Nature of Behavioural Research

Methods of knowing; Science and scientific method; Behavioural research – Concept, aim, goals and objectives; Characteristics and paradigms of research; Types of behavioural research based on applications, objectives and inquiry; Types of knowledge generated through research – historical, axiological, theoretical and conceptual knowledge, prior research studies, reviews and academic debate; Role of behavioural research in extension; Careers in behavioural research.

Unit 2: Role of Behavioural Research in Extension

Careers in behavioural research, skills needed to design and conduct research, writing research proposals

Block 2: Steps in Behavioural Research Process

Unit 1: The Behavioural Research Process

Basic steps in behavioural research – Formulating a research problem; Reviewing the literature; Identifying the variables and hypotheses; Formulating research designs, methods and tools; Selecting sample; Collecting data; Analyzing and Iiterpreting the Data; Reporting and evaluating research; Skills needed to design and conduct research; Writing research proposals.

Unit 2: Formulating a Research Problem

The research problem and research topic - definitions; Importance of formulating a research problem; Sources of research problems; Characteristics of a good research problem; Research problems in quantitative and qualitative research; Steps in formulating a research problem; Strategies for writing research problem statement; Research purpose statement; Research questions – Types, Criteria for selecting research questions, techniques for narrowing a problem into a research question; Objectives - meaning, types and criteria for judging the objectives.

Unit 3: Reviewing the Literature

Review-meaning and importance; Types of literature review – context, historical, integrative, methodological, self-study and theoretical; Literature review for quantitative and qualitative studies; Steps in conducting literature review – identify key terms, locate literature, critical evaluation and selection; organising literature

Unit 4: Identifying Variables and Hypotheses

Developing theoretical, conceptual, empirical frameworks; Approaches for identifying concepts, constructs and variables; Role of theory in behavioural research; Steps in identifying variables – domain, concepts, constructs, dimensions; Indicators; variables, definitions, premises, propositions and hypotheses; Techniques of identifying concepts, constructs and variables - Types of concepts; Types of variables–causal relationship, the study design; and the unit of measurement; Types of definitions-Types of propositions and hypotheses. Characteristics of good hypotheses; Measurement – Meaning, levels of measurement – nominal, ordinal, interval and ratio; Criteria for choosing measurement levels for variables.

Unit 5 : Formulating Research Designs, Methods and Tools

Research designs – Definition, purpose and functions; Research design as variance control - MAXMINCON Principle; Criteria for selecting a suitable research design; Classification of research designs: Quantitative designs - experimental, descriptive, comparative, correlational, survey, ex-post facto and secondary data analysis; Qualitative designs - ethnographic, grounded theory, phenomenological and Narrative research; Mixed method designs – Action research design; Translational research; Elements of research design - Research strategies, Extent of researcher interference, study setting, unit of analysis and time horizon. Sources of errors while specifying research designs. Internal and external validity; Choosing right research design; Triangulation - Importance in behavioural research, Types of triangulation; Research methods: Designing research instruments – questionnaires, interview schedules; tests – knowledge tests, behaviour performance tests; scales scales and indexes, checklists, focus groups; Steps in developing and using research methods and tools; Participatory rural appraisal.

Unit 6 : Selecting Sample

Sampling - population, element, sample, sampling unit and subject; Sampling strategies for quantitative and qualitative research; Principles of sampling; Factors affecting the inferences drawn from a sample; Types of sampling, Methods of drawing a random sample, Sampling with or without replacement, Types of sampling - Probability Sampling - Simple random sampling, Cluster sampling, Systematic sampling, Stratified random sampling and Unequal probability Sampling; Non- probability sampling - Reliance of available subjects, Purposive or judgmental sampling, accidental sampling, expert sampling, Snowball sampling, and Quota sampling; Sample size requirements for quantitative and qualitative studies; Methods for estimating sample size; Generalisation – Importance, Types of generalisations.

Unit 7 : Collecting Data

The process of collecting data – selection, training, supervision, and evaluation of field investigators; Online data collection; Errors and biases during data collection; Testing goodness of measures through item analysis - Reliability and validity; Types of validity – Content validity: Face and content validity, Criterion-related validity: concurrent and predictive validity, Construct validity: convergent, and discriminant validity, factorial validity, and nomological validity; Types of reliability - Test-Retest, Parallel forms, Inter-item consistency reliability, Split-half reliability; Factors affecting the validity and reliability of research instruments, Strategies for enhancing validity and reliability of measures; Validity and reliability in qualitative research.

Unit 8 : Analyzing and Interpreting the Data

Data coding, exploration and editing; Methods of data processing in quantitative and qualitative studies; Quantitative data analysis - parametric and non-parametric statistical analyses; Parametric analysis – Descriptive and inferential statistics, Hypothesis testing - Type I and Type II errors. Concepts in hypothesis testing - Effect Size, á, â, and Power, P Value; Multivariate data analysis – regression, factor analysis, cluster analysis, logistic regression and structural equation modelling. Guidelines for choosing appropriate statistical analysis; Statistical packages for data analysis; Methods of interpreting data and drawing inferences - The Ladder of Inference; Methods of communicating and displaying analysed data.

Unit 9: Reporting and Evaluating Research

Writing reports and research publications; Evaluation methodology; Research ethics and Plagiarism.

VII. Practicals

- Selecting a research problem and writing problem statement

- Narrowing down research problem to purpose, research questions and objectives
- Choosing, evaluating and reviewing research literature
- Selection of variables through construct conceptualisation and defining variables
- Choosing research design based on research problem
- Choosing right sampling method and estimating sample size
- Developing research methods and tools – questionnaires, interview schedule, check lists and focus group guides
- Writing a research proposal
- Field data collection using research methods and tools
- Testing reliability and validity of research instruments
- Hands on experience in using SPSS for coding, data exploration, editing, analysis and interpretation formulation of secondary tables based on objectives of research
- Writing report, writing of thesis and research articles
- Presentation of reports

VIII. Teaching methods/activities

- Lecture cum discussion
- Class exercises
- Assignment (Reading/Writing)
- Student's book/Publication review
- Student presentation
- Group work
- Research report

IX. Learning outcome

- Understand the concepts, paradigms, approaches and strategies of behavioural research
- Enable to choose research design, methods and tools suitable for the research problem
- Design research instruments skilfully and conduct research in an objective and unbiased way
- Analyse the data through appropriate analytical methods and tools and derive meaningful interpretations

X. Suggested Reading

- Babbie E. 2008. *The basics of social research*. 4th ed. Belmont, CA, USA; Thompson Wordsworth. Creswell JW. 2009. *Research design: Qualitative, quantitative, and mixed methods approaches*. Third edition. Thousand Oaks: Sage Publications.
- Creswell JW. 2012. *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Fourth edition. Boston, MA: Pearson.
- Kerlinger FN and Lee HB. 2000. *Foundations of Behavioral Research*.

Orlando, FL: Harcourt College Publishers.

- Kumar R. 2014. *Research Methodology: A Step- by- Step Guide for Beginners*. Fourth. Edition. Thousand Oaks, California: Sage Publications.
- Malhotra NK. 2010. *Marketing research: An applied orientation*. Sixth Edition. Upper Saddle River, NJ: Prentice Hall.
- NeumanWL. 2006. *Social Research Methods: Qualitative and Quantitative Approaches.* Toronto: Pearson.
- Sekaran U and Bougie R. 2013. *Research Methods for Business A Skill-Building Approach*. 6th Edition, Wiley, New York.
- Sendhil R, Kumar A, Singh S, Verma A, Venkatesh K and Gupta V. 2017. *Data Analysis Tools and Approaches (DATA) in Agricultural Sciences*. e-Compendium of Training-cum- Workshop organised at the ICAR-IIWBR during March 22-24, 2017. pp 1-126.
- Sivakumar PS, Sontakki BS, Sulaiman RV, Saravanan R and Mittal N. (eds). 2017. *Good Practices in Agricultural extension Research*. Manual on Good Practices in Extension Research and Evaluation. Agricultural Extension in South Asia. Centre for Research on Innovation and Science and Policy (CRISP), Hyderabad. India.
- Sivakumar PS and Sulaiman RV. 2015. *Extension Research in India-Current Status and Future Strategies*. AESA Working Paper 2. Agricultural Extension in South Asia.http:// www.aesanetwork.org/aesa-working-paper-2-on-extension-research-in-india-current- status-and-future-strategies-p-sethurman-sivakumar-and-rasheed-sulaiman-v-december- 2015/

I. **Course Title : Capacity Development**

II. **Course Code : EXT 505**

III. **Credit Hours : 2+1**

IV. **Why this course?**

Competent and skilful extension professionals are not naturally born. Their capacities need to be improved primarily at three different levels:

1. Pre-service capacity development – Under graduation and post-graduation studies
2. Induction capacity development – Just before job entry
3. In-service capacity development – During job

If undergone appropriately, pre-service studies help extension professionals to mainly acquire knowledge related to development. However, they are not fully ready for development work with required attitude and skills needed by an organisation. Properly planned and organized induction / in-service capacity building programmes help them to use development concepts, apply methods, exhibit attitude and skills required for development work at different levels. In short, the essence of this course is to make you understand these notions and help you to think up, manage, put into practice and evaluate capacity development programmes.

V. Aim of the course

- To understand the concepts of training, capacity building, capacity development and human resource development in the context of roles and responsibilities of extension professionals
- To discuss capacity development- approaches, strategies, needs assessment and methods / tolls
- To help you devise, organize, implement and evaluate capacity development programmes

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Capacity Development	1. Capacity Development - An Overview 2. Capacity Development – Approaches and Strategies 3. Planning and Organization of Capacity Development Programmes
2.	Capacity Development Needs Assessment - Assessment	1. Capacity Development Needs An Overview 2. Capacity Development Needs Assessment Methods
3.	Capacity Development Institutions Institutions and Management	1. Capacity Development 2. Capacity Development Project Formulation
4.	Capacity Development Process and Tools and HRD	1. Capacity Development Methods 2. Evaluation 3. Impact Assessment 4. Human Resource Development

VI. Theory

Block 1: Introduction to Capacity Development

Unit 1: Capacity Development–An Overview

Training, capacity building, capacity development and HRD-Meaning and differences; Need and principles of capacity development; Types and levels of capacities - Institutional capacities (include the rules, regulations and practices that set the overarching contextual environment), Organisational capacities (how various actors come together to perform given tasks), Individual capacities (technical, functional and leadership skills). Types of capacity building - Based on structure (structured, semi-structured & unstructured), Based on context (orientation, induction and refresher), and other categories (online, webinar, distance etc.). Components of capacity development; Capacity development cycle.

Unit 2: Capacity Development- Approaches and Strategies

Capacity Development Dilemma- Theory versus Practice, Trainee versus Task, Structured versus Unstructured, Generic and Specific; Approaches in Capacity Development -Informative approach, Participatory approach, Experimental approach/ Experiential, Performance based approach; Capacity Development Strategies - Academic strategy, Laboratory strategy, Activity strategy, Action strategy, Personal development strategy, Organizational development strategy.

Unit 3: Planning and Organization of Capacity Development Programmes

Steps in Designing and Planning of Capacity Development- Step 1. Select the participants, Step 2. Determine the participants' needs, Step 3. Formulate goal and objectives, Step 4. Outline the content, Step 5. Develop instructional activities, Step 6. Prepare the design, Step 7. Prepare evaluation form, Step 8. Determine follow-up activities; Organising capacity development programme; Operational arrangements at different stages- Before the programme, During the programme, Middle of the programme, At the end of the programme, After the programme, Follow up; Stakeholders' responsibilities.

Block 2: Capacity Development Needs Assessment

Unit 1: Planning and Organization of Capacity Development Programmes

Concept of Need Assessment; Approaches in Need Analysis- Performance Analysis,Task Analysis, Competency Study; Needs Survey.

Unit 2: Capacity Development Needs Assessment Methods

Data Collection Methods in Identifying Needs - Rational Methods (Observation, Informal talks, Complaints, Comparison, Analysis of report, Opinion poll, Buzz session, Analysis of the new programme), Empirical Methods (Job analysis, Performance evaluation, Checklist or Questionnaire Method, Tests, Critical Incident Technique, Card Sort Method, Focus Group Discussion, Interview, SWOT Analysis); Information and Skills required in Need Analysis; Identification of Needs through Task Analysis - Task identification, Task Analysis, Gap Analysis.

Block 3: Capacity Development Institutions and Management

Unit 1: Capacity Development Institutions

Capacity Developer (Trainer): Meaning and concept; Types of Capacity Developers (regular, *ad-hoc*, part time, guest and consultants); Roles of Capacity Developer (explainer, clarifier, supporter, confronter, role model, linker, motivator, translator/ interpreter, change agent); Good Capacity Developer – Qualities, skills and roles Qualities, Skills (Intrapersonal &

Inter personal), Roles (Manager, Strategist, Task Analyst, Media Specialist, Instructional Writer, Marketer, Facilitator, Instructor, Counsellor, Transfer Agent, Evaluator); Capacity Development Centres and Locations; Organisation's Role in Capacity Development.

Unit 2: Capacity Development Project Formulation

Project Proposal: Concept and Meaning; Steps in Project Formulation-Review of past proposals, Consulting experts, consultants, and previous organizers, Review past project evaluation reports, Interact with the prospective beneficiaries; Format for Writing Project Proposal (LFA).

Block 4: Capacity Development Process and HRD

Unit 1: Capacity Development Methods and Tools

Capacity Development Methods –Lecture, Discussion, Syndicate, Seminars, Conference, Symposium, Role Play, Case study, Programmed Instruction, T - group/ Laboratory methods; Factors Determining Selection of Methods - Capacity development objectives, subject matter, categories of participants, and the available resources like time, location, budget; Capacity Development Aids.

Unit 2: Evaluation

Capacity Development Programme Evaluation - Meaning & Importance; Purpose of Evaluation; Principles of Evaluation; Types of Evaluation – Formative, Summative, Kirkpatrick's four levels of evaluation; Process of Evaluation- Evaluation at the beginning, Evaluation during the programme, Evaluation at the end; Use of evaluation findings; Statistical Tools for evaluation.

Unit 3: Impact Assessment

Impact Assessment- Meaning, Need, Features, Benefits, Concepts; Indicators for Impact Assessment - Direct indicators, Indirect or proxy indicators, Quantitative indicators, Qualitative indicators, Result chain / hierarchy of indicators; Methods of Impact Evaluation- Learning retention of participants (KOSA), Impact on the job performance, Impact on organizational effectiveness, Impact on stakeholder's competency.

Unit 4: Human Resource Development

HRD: Meaning, Importance and Benefits; Types of HRD Systems & Sub-systems Career system (Manpower planning, Recruitment, Career planning, Succession planning, Retention), Work system (Role analysis, Role efficacy, Performance plan, Performance feedback and guidance, Performance appraisal, Promotion, Job rotation, Reward), Development system (Induction, Training, Job enrichment, Self-learning mechanisms, Potential appraisal, Succession development, Counselling, Mentor system), Self-renewal system (Survey, Action research, Organisational development interventions), Culture system (Vision, mission and goals, Values, Communication, Get together and celebrations, Task force, Small groups); Components of HRD System - Performance Appraisal, Potential Appraisal, Task System, Development System, Socialisation System, Governance; Functions of HRD-Organisational Development, Career Development, Capacity

Development.

VII. Practicals

- Capacity development needs assessment exercises
- Capacity development project formulation exercises
- Planning organizing and conducting an extension capacity development programme
- Designing a programme
- Writing learning objectives
- Developing objectives into curriculum
- Training plan
- Organizing capacity development workshop
- Evaluation with pre- and post-training tests
- Training methods – Practicing each method mentioned in contents as group exercises

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's book/Publication review
- Student presentation
- Group work
- Case analysis
- Guest lectures
- Review of training manuals and training evaluation studies
- Short attachments to a nearby training institute.

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Differentiate between training, capacity building, capacity development and human resource development
- Explain different levels of capacities, needs assessment approaches & methods, capacity development methods and tools
- Formulate, implement and evaluate need based capacity development programmes

X. Suggested Reading

- ADB. 2009. *Training Needs Assessment and Strategic Training Plan.*
- Bentaya GM, and Hoffmann V (Eds). 2011. *Rural Extension* Volume 3 -Training Concepts and Tools. Margraf Publishers GmbH, Scientific books, KanalstraBe 21; D-97990, Weikersheim, 191 pp.
- DFID .2003. *Promoting Institutional and Organisational Development. A*

Source Book of Tools and Techniques, Department for International Development, United Kingdom

- DoPT.2014. *Civil Services Competency Dictionary: Strengthening Human Resource Management of Civil Service*. Department of Personnel and Training, Government of India
- FAO .2010. *FAO Capacity Assessment Approach and Supporting Tools - Discussion Draft*, Food and Agriculture Organisation of the United Nations
- FAO .2012. *Capacity Development: Learning Module 2.* FAO Approaches to Capacity Development inProgramming. Processes and Tools, Food and Agriculture Organisation ofthe United Nations
- FAO .2012. *Corporate Strategy on Capacity Development*.
- FAO .2013. *Capacity Development: Learning Module 4*. Organization Analysis and Development Food and Agriculture Organisation of the United Nations
- GFRAS. 2012. *The New Extensionist: Roles, Strategies, and Capacities to Strengthen Extension andAdvisory Services*, Global Forum for Advisory Services
- GFRAS. 2015. *The New Extensionist: Core Competencies for Individuals*, GFRAS Brief 3. Horton D. 2002. *Planning, Implementing, and Evaluating Capacity Development*. ISNAR Briefing Paper 50.
- ICAR 2015. *Training Policy 2015*, Indian Council of Agricultural Research.
- IISD 2015. *Appreciative Inquiry and Community Development*. International Institute for SustainableDevelopment.
- LENCD 2011. *How to assess existing capacity and define capacity needs*, Learning Network onCapacity Development.
- Maguire. 2012. *Module 2: Agricultural Education and Training to Support Agricultural Innovation Systems.Overview. Agricultural Innovation Systems: An Investment Source book*. The World Bank.
- Mbabu AN and Hall A. 2012. *Capacity Building for Agricultural Research For Development- Lessons from Practice in Papua New Guinea*. United Nations University-Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT). https://www.merit.unu.edu/archive/docs/hl/201302_Capacity%20Building%20for%20 Agricultural%20Research%20Development_Final.pdf
- Mittal N, Sulaiman RV and Prasad R M. 2016. *Assessing Capacity Needs of Extension and Advisory Services a Guide for Facilitators*. Agricultural Extension in South Asia. http:// www.aesanetwork.org/assessing-capacity-needs-of-extension-and-advisory-services-a- guide-for-facilitators/
- Mishra DC. 1990. *New Directions in Extension Training*. Directorate of Extension, Ministry of Agriculture, Govt. of India, New Delhi.

- OECD/DAC. 2006. *The Challenge of Capacity Development: Working Towards Good Practice*, Organisation for Economic Cooperation and Development.
- Pretty JN, Gujit I, Thompson J, and Scoones I. 1995. *A Trainer's Guide for Participatory Learning and Action*. IEED Participatory Methodology Series.
- Rolf PL and Udai P. 1992. *Facilitating Development: Readings for Trainers, Consultants and Policy-makers*, New Delhi: Sage Publications, pp. 359
- Rolf PL and Udai P. 1990. *Training for Development*, (3rd edn) by (West Hartford, Kumarian Press, 1990, pp. 333.
- SIDA.2000. *Capacity Development*. SIDA Working Paper No. 4. Analysis of Needs for Capacity Development.
- SIDA. 2000. Working Paper No. 4. *Analysis of Needs for Capacity Development*
- Sulaiman RV and Mittal N. 2016. *Capacity Needs of Extension and Advisory Services* (EAS) *in South Asia*. Policy Brief No 1. Agricultural Extension in South Asia. http://www.aesanetwork.org/policy-brief-no-1-capacity-needs-of-extension-and-advisory-services- eas-in-south-asia/
- Swanson BE and Rajalahti R. 2010. *Strengthening Agricultural Extension and Advisory Services.* A Guide for Facilitators.
- TAP. 2013. *Capacity Development for Agricultural Innovation Systems - Key Concepts and Definitions*. Tropical Agricultural Platform
- TAP. 2016. *Common Framework on Capacity Development for Agricultural Innovation Systems*.
- Guidance Note on Operationalization, Tropical Agricultural Platform
- UNDP. 1998. *Capacity Assessment and Development in a Systems and Strategic Management Context*. Technical Advisory Paper No. 3. Management Development and Governance Division Bureau forDevelopment Policy, January 1998, United Nations Development Programme
- UNDP. 1998. *CapacityAssessment and Development in a Systems and Strategic Management Context*. Technical Advisory UNU-MERIT, Netherlands.
- UNDP. 2008. *Capacity Assessment Methodology. User's Guide*. Capacity Development Group. Bureaufor Development Policy.
- UNDP. 2009. *Capacity Development: A UNDP Primer*, United Nations Development Programme WAC. 2013. *Assessing Capacity Needs and Strategy Development for Grassroots Rural*
- *Institutions: A Guide for Facilitators*. World Agroforestry Centre (WAC)

Websites

TAP–Tropical Agriculture Platform for Capacity Development– https://www.tapipedia.org/ FAO–FAO Capacity Development– http://www.fao.org/capacity-development/en/ GFRAS–Global Forum for Rural Advisory Services– http://www.g-fras.org/en/ AESA–Agricultural Extension in South Asia– http://www.aesanetwork.org/

I. Course Title : ICTs for Agricultural Extension and Advisory Services

II. Course Code : EXT 506

III. Credit Hours : 2+1

IV. Why this course?

Information and Communication Technologies (ICTs) are continuously evolving. More ICT applications having better relevance to extension and advisory services (EAS) are currently available considering the human and other resource constrains faced by EAS, ICTs can supplement and complement EAS extension efforts in a cost-effective way. Extension professionals should have sound knowledge of ICTs and comprehensive understanding on its various applications for effectively deploying these in EAS provision. This course will provide knowledge and hands-on-experience on ICT applications relevant for EAS.

V. Aim of the course

- To discuss different ICT initiatives, knowledge management process and application aspects
- To orient students on advances in smart/ disruptive technologies and data analytics
- Hands on experience in navigating ICTs

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Information and Communication Technologies (ICTS)	1. ICTs- Concepts and Status 2. ICTs in Knowledge Management
2.	Application of ICTs in Extension and advisory services	1. ICT Applications 2. ICT Expert Systems 3. ICT Networks
3.	Knowledge management and Standards	1. Policies in Knowledge Management 2. Web Standards 3. Social Media Applications to engage audience
4.	Smart and disruptive Technologies and advanced analytics for agricultural extension	1. Smart Technologies 2. Human Computer Interactions

VI. **Theory**

Block 1: Introduction to Information and Communication Technologies (ICTs) and E-extension

Unit 1: ICTs- Concepts and Status

ICTs- meaning, concepts, basics of ICTs, global and national status, types and functions of ICTs, innovations, meaning of e-Governance, e-learning, mLearning, advantages and limitations of ICTs.

Unit 2: ICTs in Knowledge Management

Knowledge management-meaning, approaches and tools. Role of ICTs in Agricultural Knowledge Management.

Unit 3: e-Extension Initiatives in Agriculture and Allied sectors

e-Extension, overview on global and national e-extension initiatives, Inventory of e-Extension initiatives in agriculture and allied sectors from central and state governments, ICAR, SAUs, private sector and NGO initiatives in India.

Block 2: Application of ICTs in Extension and Advisory Services

Unit 1: ICT Applications

Knowledge centres (tele centres), digital kiosks, websites and web portals, community radio, farmers call centres, mobile phone based advisory services and mobile applications (mExtension, mLearning), self-learning CDs on package of practices, social media, digital videos, market intelligence and information systems- ICT enabled Supply-Chains and Value-Chains/ e-Marketing (e-NAM, Agmarknet, *etc*.).

Unit 2: ICT Expert Systems

Expert System/ Decision Support System/ Management Information Systems, Farm Health Management & Intelligence System for Plant Health, Animal Health, Soil Health, Fishery, Water, Weather, etc.

Unit 3: ICT Networks

Global and regional knowledge networks, international information management systems, e-Learning platforms (MOOCS, Course CCRA, EduEx, *etc*), e-Governance systems; digital networks among extension personnel, Farmer Producers Organisations (FPOs)/ SHGs/ Farmers Groups.

Block 3: Knowledge Management and Standards

Unit 1: Policies in Knowledge Management

Global policy/ Standards on e-Governance, National policy on e-governance, Open Data / Open Gov Standards and Open Source etc; Language Technology Applications; National e-Agriculture policy/ Strategies/ guidelines.

Unit 2: Web Standards

Web standards, creating and writing for web portals, development of mobile applications, developing digital videos- story board- video recording- video editing,types of blogs and writing guidelines.

Unit 3: Social Media Applications to Engage Audience

Video conference, live streaming and webinars, types and functions of social media applications, guidelines for preparing social media content, engaging audience and data-analytics.

Block 4: Smart and Disruptive Technologies and Advanced Analytics for Agricultural Extension

Unit 1: Smart Technologies

Open technology computing facilities, System for data analytics/ mining/ modelling/ Development of Agricultural simulations; Remote Sensing, GIS, GPS, Information Utility (AIU); disruptive technologies- Analysis; Internet of Things (IoTs), Drones, Artificial intelligence (AI), block chain technology, social media and Big Data analytics for extension.

Unit 2: Human Computer Interactions

Human Centered Learning/Ergonomics/ Human Computer Interactions-Meaning; Theories of multimedia learning - Sweller's cognitive load theory, Mayer's cognitive theory of multimedia learning, Schnotz's integrative model of text and picture comprehension, van Merriënboer's four-component instructional design model for multimedia learning; Basic Principles of Multimedia Learning - Split-attention, Modality, Redundancy, Coherence, Signaling, segmenting, pre-training, personalisation, voice embodiment; Advanced principles - Guided discovery, worked examples, Self-explanation, drawing, feedback, multiple representation, Learner control, animation, collaboration, prior knowledge, and working memory. Designing ICT gadgets based on human interaction principles - Interactive design-Meaning, importance; Approaches of interactive design - user-centered design, activity- centered design, systems design, and genius design; Methods of interactive design - Usability testing methods.

VII. Practicals

- Content and client engagement analysis
- Designing extension content for ICTs
- Creating and designing web portals, blogs, social media pages
- Developing digital videos
- Live streaming extension programmes and organising webinars
- Working with farmers call centres
- Engaging with professional digital networks
- Writing for digital media
- Generating innovative ideas for application of ICT in Agricultural Extension and Advisory Services

VIII. Teaching methods/activities

- Lecture
- Guest lectures
- Assignment (Reading/Writing/ developing mApps/ media management/Socialmedia initiatives)

- Student’s book/Publication review
- Student presentation
- Group work
- Student’s interview of ICT practitioners/ champions
- Documenting good practices and case studies
- Review of ICT policy documents and guidelines/ standards
- Short internship with ICT projects

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the importance of the ICTs in EAS
- Understand the ICT application aspects
- Critically evaluate ICT initiatives and smart/disruptive technologies
- To execute extension functions by applying ICTs and
- Engage stakeholders in knowledge management process

X. Suggested Reading

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Extension- MEAS-Discussion-Paper.pdf

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FAO–Food and Agricultural Organisation (Research and Extension) http://www.fao.org/research-and-extension/en/

CTA–The Technical Centre for Agricultural and Rural Cooperation: Digitalization– https://www.cta.int/en/channel/digitalisation-sid05951b8c7-e611-4f34-9ae6-8c0fc0c822bc

GFRAS–Global Forum for Rural Advisory Services–http://www.g-fras.org/en/

AESA–Agricultural Extension in South Asia–http://www.aesanetwork.org/

I. Course Title : Evaluation and Impact Assessment

II. Course Code : EXT 507

III. Credit Hours : 2+1

IV. Why this course?

Many organizations now look for experts to evaluate development projects and developmental interventions. It is now required that impact be assessed whenever any development programme is implemented. Thus, the extension professionals need to have good understanding of the theory and practice of programme evaluation and impact assessment. This course, thus, has been designed to help students develop as extension professionals who can plan and conduct systematic assessments of the results and impacts of extension programmes.

V. Aim of the course

- To orient students on the importance of evaluation and impact assessment
- To develop capacities for evaluation and impact assessment
- Discuss ways of conducting evaluations and impact assessment

The course is organized as follows:

No	Blocks	Units
1.	Programme Evaluation	1. Introduction to Evaluation 2. Evaluation Theories
2.	Evaluation Process	1. How to Conduct Evaluation 2. Evaluating the Evaluation
3.	Programme Management Techniques	1. SWOT Analysis and Bar Charts 2. Networks
4.	Programme Evaluation Tools	1. Bennett's Hierarchy of Evaluation

		2. Logic Framework Approach
5.	Impact Assessment	1. Introduction to Impact Assessment 2. Impact Assessment Indicators 3. Approaches to Impact Assessment 4. Environment Impact Assessment

VI. Theory

Block 1: Programme Evaluation

Unit 1: Introduction to Evaluation

Concept of Evaluation: Meaning and concept in different contexts; Why Evaluation is Done and When? Programme planning, analyse programme effectiveness, decision making, accountability, impact assessment, policy advocacy; Objectives, types, criteria and approaches of programme evaluation, evaluation principles; the context of program evaluation in agricultural extension; Role and credibility of evaluator: Role as educator, facilitator, consultant, interpreter, mediator and change agent. Competency and credibility of evaluator.

Unit 2: Evaluation Theories

Evaluation theory vs. practice – synergistic role between practice and theory in evaluation; Evaluation theories - Three broad categories of theories that evaluators use in their works - programme theory, social science theory, and evaluation theory (other theories/ approaches - Utilization-Focused Evaluation & Utilization-Focused Evaluation (U-FE) Checklist, Values Engaged Evaluation, Empowerment Evaluation, Theory-Driven Evaluation). Integration between theory and practice of evaluation:

–evaluation forums, workshops, conferences and apprenticeship/ internship.

Block 2: Evaluation Process

Unit 1: How to Conduct Evaluation

Ten Steps in programme evaluation: (1) Identify and describe programme you want to evaluate (2) Identify the phase of the programme(design, start-up, on- going, wrap-up, follow-up) and type of evaluation study needed (needs assessment, baseline, formative, summative, follow-up) (3) Assess the feasibility of implementing an evaluation (4) Identify and consult key stakeholders (5) Identify approaches to data collection (quantitative, qualitative, mixed) (6) Select data collection techniques (survey interviews and questionnaires with different types) (7) Identify population and select sample (sampling for evaluation, sample size, errors, sampling techniques (8) Collect, analyse and interpret data (qualitative and quantitative evaluation data analysis) (9) Communicate findings (reporting plan, evaluation report types, reporting results, reporting tips, reporting negative findings (10) Apply and use findings (programme continuation/ discontinuation, improve on-going programme, plan future programmes and inform programme stakeholders).

Unit 2: Evaluating the Evaluation

Evaluating the Evaluation - 10 s teps as above with focus on conceptual clarity, representation of programme components and stakeholders, sensitivity, representativeness of needs, sample and data, technical adequacy, methods used for data collection and analysis, costs, recommendations and reports.

Block 3: Programme Management Techniques

Unit 1: SWOT Analysis and Bar Charts

SWOT Analysis – Concept, origin and evolution; SWOT as a Programme Management Tool; Conducting SWOT Analysis - Common Questions in SWOT Analysis; Advantages and Disadvantages of SWOT; Bar Charts (Gantt Charts and Milestone Charts) - Characteristics, advantages and limitations.

Unit 2: Networks

Networks – Introduction, origin and widely used networks Programme Evaluation and Review Technique (PERT) and Critical Path Method (CPM), differences between PERT and CPM, advantages and disadvantages. Networks Terminology – Activity, Dummy activity, Event (predecessor event, successor event, burst event, merge event, critical event), Earliest Start Time (EST), Latest Start Time (LST), Critical Path, Critical Activity, Optimistic time (T_o), Pessimistic time (P_o), Most likely time (T_M), Expected time (T_E), Float or Slack, Event Slack, Lead time, Lag time, Fast tracking, Crashing critical path, Acclivity Table, Danglers, Normal Time. Rules for Preparation of Networks and Steps in Network Preparation with example.

Block 4: Programme Evaluation Tools

Unit 1: Bennett’s Hierarchy of Evaluation

Introduction to Bennett’s hierarchy – Background and description; Relation between programme objectives & outcomes at 7 levels of Bennett’s hierarchy – Inputs, activities, participation, reactions, KASA changes, practice and behaviour changes, end results. Advantages and Disadvantages of Bennett’s hierarchy

Unit 2: Logic Framework Approach (LFA)

Introduction to LFA – Background and description; Variations of LFA - Goal Oriented Project Planning (GOPP) or Objectives Oriented Project Planning (OOPP); LFA Four-by-Four Grid – Rows from bottom to top (Activities, Outputs, Purpose and Goal & Columns representing types of information about the events (Narrative description, Objectively Verifiable Indicators (OVIs) of these events taking place, Means of Verification (MoV) where information will be available on the OVIs, and Assumptions). Advantages and Disadvantages of LFA.

Block 5: Impact Assessment

Unit 1: Introduction to Impact Assessment

Concept of Impact Assessment: Meaning, concept and purpose in different contexts; Impact Assessment Framework: Meaning of inputs, outputs, outcomes, impacts and their relation with monitoring, evaluation and impact assessment.

Unit 2: Impact Assessment Indicators

Indicators for impact assessment – meaning and concept; Selecting impact indicators; Types of impact indicators for technology and extension advisory services - social and behavioral indicators, socio-cultural indicators, technology level indicators, environmental impact assessment indicators and institutional impact assessment indicators.

Unit 3: Approaches for Impact Assessment

Impact assessment approaches – Quantitative, qualitative, participatory and mixed methods with their advantages and disadvantages; Quantitative Impact Assessment Types – Based on Time of Assessment (Ex-ante and ex-post), Based on Research Design (Experimental, Quasi experimental, Non-experimental). Econometric Impact Assessment: - (Partial Budgeting Technique, Net Present Value, Benefit Cost Ratio, Internal Rate of Return, Adoption Quotient, *etc*). Qualitative and Participatory Impact Assessment Methods.

Unit 4: Environment Impact Assessment (EIA)

Concept of EIA – Introduction, What it is? Who does it? Why it is conducted? How it is done?; Benefits and important aspects of EIA-risk assessment, environmental management and post product monitoring. Environmental Components of EIA – air, noise, water, biological, land; Composition of the expert committees and steps in EIA process - screening, scoping, collection of baseline data, impact prediction, mitigation measures and EIA report, public hearing, decision making, monitoring and implementation of environmental management plan, assessment of alternatives, delineation of mitigation measures and EIA report; Salient Features of 2006 Amendment to EIA Notification - Environmental Clearance/Rejection, participants of EIA; Shortcomings of EIA and How to improve EIA process?

VII. Practicals

- Search the literature using web / printed resources and identify evaluation indicators for the following:
  - Utilization-Focused Evaluation
  - Values Engaged Evaluation
  - Empowerment Evaluation
  - Theory-Driven Evaluation
- Visit the Directorate of Extension in your university and enquire about extension programmes being implemented / coordinated by the Directorate. Develop an evaluation proposal of any one programme using ‘Ten Steps in Programme Evaluation’ discussed in the theory class.

- Review any comprehensive programme evaluation report from published sources. Evaluate the report and write your observations following the 'Evaluating the Evaluation' approach.
- Identify at least four agriculture development programmes and their objectives being implemented in your state. Write two attributes each on Strengths, Weaknesses, Opportunities and Threats related to the identified programme objectives in the SWOT grid.
- Identify an on-going development programme and make-out 6 activities from the programme.
- Draw a Gantt chart for 12 months programme activities.
- Write a report on evaluation hierarchy levels and indicators as per Bennett's hierarchy of evaluation for any development programme or project.
- Develop LFA four-by-four grid for any development programme or project with activities, outputs, purpose and goal and objectively verifiable indicators, means of verification & assumptions.
- Visit a nearby KVKs / ATIC. Select any agriculture technology with package of practices and extension advisory services promoted by KVK / ATIC. Identify impact assessment indicators for social and behavioral indicators, socio-cultural indicators, technology level indicators, environmental impact assessment indicators and institutional impact assessment indicators.
- Refer any Environment Impact Assessment report and analyse steps in EIA. Write your observations.
- Socio-economic and environmental impact assessment of any development programme/project using appropriate tools.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's book/Publication review
- Student presentation
- Group work
- Guest lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to: Develop competencies in the areas of evaluation planning, indicator development, conducting evaluation and impact assessment and writing reports.

X. Suggested Reading

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- Bagnol B. 2014. *Conducting participatory monitoring and evaluation*. Pages 81-85 in FAO, Decision tools for family poultry development. FAO Animal Production and Health Guidelines, No. 1 6. Rome, Italy: FAO.
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- Boyle R and Le Maire D. 1999. *Building effective evaluation capacity: lessons from practice*. New Brunswick, NJ: Transaction Publishers.
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challenges and problems. Australian Journal of Experimental Agriculture, Vol. 40 No. 4 pp. 519–526.

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- Neuchatel Group. 2000. *Guide for Monitoring, Evaluation and Joint Analyses of Pluralistic Extension Support.* Lindau, Switzerland: Neuchâtel Group.
- www.g-fras.org/fileadmin/UserFiles/Documents/Frames-and-guidelines/M_E/Guide-for- Monitoring-Evaluation-and-Joint-Analysis.pdf
- Njuki J, Mapila M, Kaaria S and Magombo T. 2008. *Using community indicators for evaluating research and development programmes: Experiences from Malawi. Development in Practice* 18(4): 633–642.
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- www.oecd.org/dataoecd/63/50/2065863.pdf (accessed 6 June 2011)
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- USAID .2011. *Evaluation policy.* Washington, D.C., USA: Bureau for Policy and Planning. Venkateswarlu, K and Raman, K.V. 1993. *Project Management Techniques for R&D in Agriculture.* Sterling Publishers Pvt.Ltd., New Delhi.
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Websites

Better Evaluation– www.betterevaluation.org
TAP– Tropical Agriculture Platform: Monitoring and Evaluation - www.tapipedia.org GFRAS– Global Forum for Rural Advisory Services http://www.g-fras.org/en/
AESA– Agricultural Extension in South Asia http://www.aesanetwork.org/
USAID– United States Agency for International Development: Evaluation https://www.usaid.gov/evaluation
https://education.illinois.edu/faculty/jennifer-greene

I. **Course Title** : **Managing Extension Organizations**

II. **Course Code** : **EXT 508**

III. **Credit Hours** : **2+1**

IV. **Why this course?**

Organizations need to follow management principles, objectives and organizational processes. The extension organizations including management of agricultural extension services need to be managed for effectiveness and efficiency. This calls for key business management skills to be learnt by the students so that they can run extension organizations, and extension and advisory services efficiently using the principles, practices, knowledge and skills required for effective management.

V. **Aim of the course**

- To orient students on the importance of knowledge and skills on various management functions, as applicable to extension organizations
- Discuss ways of running extension services as managers of agri-ventures
- To develop capacities for becoming effective managers of agri-ventures.

The course is organized as follows:

No	Blocks	Units
1.	Basics of Management	1. Management- An Over view
2.	Management in different types of Extension organizations	1. Extension Management in public, private sector and other sectors 2. Concepts in Management
3	Motivation and Organizational Communication	1. Motivation and Communication 2. Supervision and Control

VI. **Theory**

Block 1: Basics of Management

Unit 1: Management- An Over view

Management and importance; Extension and theories of management. Management, administration and supervision - meaning, definition and scope; Approaches to management, Principles, functions and levels of management; Qualities and skills of a manager; Interpersonal relations in the organization; Reporting and budgeting

Block 2: Management in different types of Extension Organizations

Unit 1: Extension Management in public, private sector and other sectors

Extension management (POSDCORB) in public sector, Department of Agriculture, Agricultural Technology Management Agency (ATMA), Krishi Vigyan Kendra (KVK), SAUs, ICAR Institutes, Private sector, Cooperatives, NGOs, FPOs etc. Organisational Structure, Relations between different units- Challenges in management Decision making – Concept, Types of decisions, Styles and techniques of decision making, Steps in DM Process, Guidelines for making effective decisions; Human Resource Management: Manpower planning, Recruitment, Selection, Placement and Orientation, Training and Development; Dealing with fund and staff shortages in different extension organizations (KVK, ATMA etc.); Leadership – Concept, Characteristics, Functions, Approaches to leadership, Leadership styles; Authority and responsibility, Delegation and decentralization, line and staff relations; Challenges of co-ordination in extension organizations; Managing interdepartmental coordination and convergence between KVK, ATMA and line departments; Coordinating pluralism in extension services; Challenges in managing public-private partnerships (PPPs) at different levels in agricultural development in general and extension in particular; Performance appraisal – Meaning, Concept, Methods.

Block 3: Motivation and Organizational Communication

Unit 1: Motivation and Communication

Managing work motivation – Concept, Motivation and Performance, Approaches to motivation, team building; Organizational Communication –

Concept, Process, Types, Networks, Barriers to Communication; Mentoring, Time management, Team work and team-building strategies; Modernization of information handling.

Unit 2: Supervision and Control

Supervision – Meaning, Responsibilities, Qualities and functions of supervision, Essentials of effective supervision; Managerial Control – Nature, Process, Types, Techniques of Control, Observation, PERT and CPM, Management Information Systems (MIS): Concept, tools and techniques, MIS in extension organizations; Six Sigma, QCC, TQM, MBO.

VII. Practicals

- Simulated exercises on techniques of decision making
- Study the structure and function of agro-enterprises, Designing organizational structure/ organograms.
- Group activity on leadership development skills
- Simulated exercises to understand management processes
- Field visit to extension organizations (ATARI, KVKs, NGOs), FPOs, dairy cooperatives to understand the functions of management
- Practical exercises on PERT & CPM
- Group Exercises on development of short term and long term plans for agro- enterprises
- Developing model agriculture-based projects including feasibility study, financial planning and cost-benefit analysis

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's book/Publication review
- Student presentation
- Group work
- Student's interview of officers engaged in EAS
- Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Turn good managers of extension and advisory services including agri-ventures, FPOs, cooperatives etc.
- understand the key business skills needed for managing agribusinesses and managing the value chains
- Critically evaluate the management functions to make extension systems efficient by applying management principles and good practices of effective management
- Engage in management of extension organizations

X. Suggested Reading

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I. Course Title : Enabling Innovation

II. Course code : EXT 509

III. Credit Hours : 1+1

IV. Why this course?

An effective process of agricultural innovation is a pre-condition for meeting the global challenge of feeding the growing world population and reducing poverty. Ideas about innovation have evolved considerably over the past 4 decades. A frequently used term in the discussions around innovation in agriculture is 'Agricultural Innovation Systems' (AIS). The AIS is increasingly recognized as a useful framework to diagnose innovation capacity, design investment and organise scaling up interventions. Extension and Advisory Services (EAS) are integral to AIS. Extension professionals should have sound knowledge on how to scale up new knowledge and thereby enabling innovation and impact and their roles in strengthening AIS. This course aims to provide these perspectives.

V. Aim of the course

The aim of this course is to introduce the new perspectives related to "innovation" and help learners to apply the AIS framework especially in dealing with scaling up knowledge. It discusses the different ways to explore AIS including the roles of different actors and the enabling environment (including institutions and policies) in enabling innovation. The course also aims to broaden the understanding of students in scaling up knowledge and orient students to varied tools and approaches to scaling up

The course is organized as follows:

No	Blocks	Units
1	Agricultural Innovation Systems	1. Agricultural Innovation Systems: Concepts and Elements 2. Enabling Innovation
2	Scaling Up Knowledge for Innovation	1. Scaling Up: Tools, Approaches and Pathways

VI. Theory

Block 1: Agricultural Innovation Systems

Unit 1: Agricultural Innovation Systems: Concepts and Elements

Origins of the innovation systems concept-Innovation vs Invention; Agricultural Innovation System (AIS) -ToT, FSR, AKIS and AIS compared, Key insights from AIS: How Innovation takes place; Role of different actors in AIS; Importance of interaction and knowledge flows among different actors, Role of Communication in Innovation Process; Role of Extension in AIS, Different views to analyze AIS: structural view, functional view, process view and capacity view.

Unit 2: Enabling Innovation

Role of enabling environment: Policies and institutions in enabling innovation; Role of Government-Innovation Policy: Achieving coordination and policy coherence;

Innovation Platforms; Role of Innovation Brokers, Methodologies for AIS Diagnosis: Typologies of existing methodologies-strengths and limitations; Assessing Extension and Advisory Services within AIS; Capacity Development in AIS: Strengthening capacities to innovate.

Block 2: Scaling Up Knowledge for Innovation

Unit 1: Scaling Up: Tools, Approaches and Pathways

Scaling Up: Definitions; Changing views on scaling up: Approaches to Scaling Up: Push, pull, plant, probe: Scaling up pathways: Drivers and spaces for scaling up; Framework and Tools for Scaling up: Planning and implementing a scaling up pathways; Scalability assessment tools; Role of policies in scaling up: Influencing policies for scaling up; Innovation Management for scaling up knowledge and implications for Extension and Advisory Services.

VII. Practical

- Identify one crop/commodity sector and use AIS framework to diagnose actors and their roles, patterns of interaction, institutions determining interaction and the enabling policy environment and develop a AIS Diagnosis Report (Review and Key informant interviews)
- Undertake a case study on a successful case of scaling up knowledge and identify factors that contributed to its success
- Identify one specific knowledge (a technology, an approach) that has been recently introduced and develop an up-scaling strategy

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student’s book/Publication review
- Student presentation
- Group work

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate and apply AIS framework in different contexts
- Enhance their knowledge and skills related to enabling innovation

- Diagnose AIS and design interventions for improvement and
- Design scaling up strategies to achieve innovation and impact

X. Suggested Reading

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Websites

AESA- Agricultural Extension in South Asia– http://www.aesanetwork.org/

FAO- Food and Agricultural Organisation (Research and Extension) http://www.fao.org/research-and-extension/en/

GFRAS- Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

KIT- Royal Tropical Institute (KIT)-Sustainable Economic Development– https://www.kit.nl/sed/

TAPipedia - Tropical Agriculture Platform– https://www.tapipedia.org/

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I. Course Title : Gender Mainstreaming

II. Course Code : EXT 510

III. Credit Hours : 2+1

IV. Why this course?

Gender as a concept has gained well deserved attention globally. Development planners and policy makers have realized that gender implications need to be considered while planning and implementing programmes and projects for their desired impacts. Conversely, the impacts of programmes on men and women also vary due to their different socially ascribed roles and responsibilities. Extension professionals need to understand the concept of gender and its implications on agricultural and rural development and their skills need to be built for critically identifying and analysing gender implications. This course is designed to meet these requirements.

V. Aim of the course

- To orient students on the importance of "Gender mainstreaming" as well as the other concepts related to gender. The students will be able to understand the gender roles and responsibilities and how in the present times, the roles may be shifting
- To discuss ways and various techniques for conducting gender analysis theoretically and practically as well as the prerequisites for gender analysis
- To develop capacities for identifying and addressing gender implications in all development programmes related to agriculture and allied sectors, climate change adaptation and livelihood security, as well as addressing gender issues through application of extension methods including PRA and PLA

The course is organized as follows:

No	Blocks	Units
1.	Why Gender Matters	1. Historical Perspective of Gender 2. Agrarian Importance of Gender
2.	Gender Related Concepts, Analysis, Gender and Technology	1. Gender Related Concepts and Divides 2. Gender Analysis 3. Gender and Technology
3.	Gender Mainstreaming and Women Empowerment	1. Gender Mainstreaming 2. Women Empowerment 3. Global Best Practices, Policies and Frameworks 4. Entrepreneurship Development for Women

VI. Theory

Block 1: Why Gender Matters?

Unit 1: Historical Perspective of Gender

Historical perspective of gender: Feminism and emergence of gender as a concept, Scope of gender studies in agriculture and rural development.

Unit 2: Agrarian Importance of Gender

Agrarian Importance of Gender: Understanding the importance of gender in national and global agriculture-Key gender issues and challenges in agriculture - Gender and value chain- Global actions to address gender-needs and strategies to address gender and women empowerment.

Block 2: Gender Related Concepts, Analysis, Gender and Technology

Unit 1: Gender Related Concepts and Divides

Gender related concepts and divides: Understanding of the concepts of gender, gender equality and equity, gender balance, gender blindness, gender relations, gender neutrality, gender bias and discrimination, gender rights, gender roles and responsibilities. Gender budgeting, Gender divides and their implications such as gender digital divide, gender access to resources and inputs divide, gender mobility divide, gender wage divide, Gender needs: practical and strategic.

Unit 2: Gender Analysis

Gender analysis: Importance, usage, prerequisites, techniques of gender analysis- Tools for gender analysis.

Unit 3: Gender and Technology

Gender and technology: How gender and technology impact each other, Gender neutral technology, Gender sensitive technology, Gender supportive assistance in technology adoption-Gender in agricultural research and extension.

Block 3: Gender Mainstreaming and Women Empowerment

Unit 1: Gender Mainstreaming

Gender mainstreaming: Importance of gender mainstreaming in agriculture, Extension strategies to address gender issues such as gender and health, nutrition, gender in agricultural value chains, gender and climate change adaptation, gender and globalization& liberalization for mainstreaming gender concerns into the national programmes and policies.

Unit 2: Women Empowerment

Women Empowerment: Importance of women empowerment, Current national women empowerment and gender indices. Women empowerment approaches (technological, organizational, political, financial, social, legal and psychological), Case studies based on experiences and learning from various development and rural development programmes. Sensitization on transgender empowerment.

Unit 3: Global Best Practices, Policies and Frameworks

Global Best Practices, Policies and Frameworks: Global best practices, women empowerment and gender mainstreaming models and frameworks for addressing gender concerns in agriculture, approaches of various organizations: gender mainstreaming and special women focused programmes in agriculture and rural development. Gendered planning.

Unit 4: Entrepreneurship Development for Women

Entrepreneurship development for women: Women entrepreneurship development in agriculture and agro processing: current status, women led enterprises, supporting organizations and schemes, Govt. policies, entrepreneurship development programme and process for women in agriculture.

VII. Practicals

- Visit to a village for understanding rural gender roles and responsibilities as groups, followed by class presentation by groups
- Exercises for capturing shifts in gender roles and responsibilities
- Conducting gender analysis in a village using gender analysis techniques
- Visit to agencies supporting women empowerment followed by report presentation. Each student to visit a different organization such as State Rural Livelihood Mission, Women Development Corporation, Department of Agriculture, Important NGOs working for women empowerment
- Exercises for identification and prioritization of issues affecting/needs for women empowerment
- Interaction with a successful women entrepreneurs/ SHG

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's book/Publication review
- Student presentation
- Group work
- Student's interview of key policy makers
- Case Analysis
- Guest lectures
- Review of policy documents
- Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the importance of addressing agrarian gender concerns in the context of sustainable livelihoods and national development
- Understand the various concepts related to gender and the application of these concepts for women empowerment and gender mainstreaming
- Critically evaluate the various agricultural development, rural development programmes, schemes, policies and strategies for women empowerment within the context of achieving gender equity
- How to engage in gender analysis and collect and analyse sex-disaggregated data for developing strategies for women empowerment and gender mainstreaming

X. Suggested Reading

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Websites

AESA- Agricultural Extension in South Asia– http://www.aesanetwork.org/

GFRAS- Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

INGENAES- Integrating Gender and Nutrition within Agricultural Extension Services– https://www.agrilinks.org/activities/ingenaes-integrating-gender-and-nutrition-within- agricultural-extension-services

RRW- Reaching Rural Women– http://www.reachingruralwomen.org/

UN WOMEN– http://www.unwomen.org/en

Course Title with Credit Load for Ph.D. in Agricultural Extension Education

Course Code	Title of Course	Credit Hours
EXT-601*	Policy Engagement and Extension	2+1
EXT-602*	Methodologies for Social and Behavioural Sciences	2+1
EXT-603*	Technology Commercialization and Incubation	2+1
EXT-604*	Educational Technology and Instructional Design	2+1

Minor Courses 06

EXT-605	Risk Management and Climate Change Adaptation	2+1
EXT-606	Livelihood Development	1+1

EXT-607	Facilitation for People centric Development	2+1

Supporting Courses 05

STAT	Multivariate Statistical Methods for Extension Research	2+1
COM	Multimedia and Applications	1+1

Seminars 2

EXT-691	Doctoral Seminar-I	1+0
EXT-692	Doctoral Seminar-II	1+0
	ii. Thesis / Research	75
	Total	100

I. **Course Title** : **Policy Engagement and Extension**

II. **Course Code** : **EXT 601**

III. **Credit Hours** : **2+1**

IV. **Why this course?**

Extension's performance in any country to a large extent is dependent on the wider policy and institutional context prevailing at the national level. At the organizational level, extension should have capacities to influence policies that affect their performance. To effectively influence policies, extension professionals need to generate not only sound evidence of its impact, but also capacities to engage with policy relevant actors especially at various levels. While few countries have developed specific extension policies, there has been very limited success in translating these policies into programmes and operational guidelines. Lack of policy relevant research to generate evidence on extension's impact; poor documentation of successful initiatives, and lack of training on engaging with policy relevant actors have all contributed to this. Extension professionals, often encounter situations where existing policy constraints development interventions or where new policies could better support development. This course is aimed at developing these capacities to successfully engage with policy actors and bringing about desirable policy changes to strengthen extension.

V. **Aim of the course**

- To orient students on the importance of policies in shaping extension's performance
- To discuss ways of generating policy relevant evidence to influence policies
- To develop capacities to engage with policy actors and the policy development process

The course is organized as follows:

No	Blocks	Units
1.	Why policies matter?	1. Understanding Policy 2. Policy Advocacy and Tools 3. Policy Analysis 4. Policy Development Process
2.	Using evidence to influence Policy Change	1. Influencing Policy Change 2. Global Experience with Extension Policy

VI. **Theory**

Block 1: Why Policies Matter?

Unit 1: Understanding Policy

Why policies are important for extension? Role in providing structure, ensure funding and framework for providing functions-examples; Policy: definitions and types: Is policy a product or a process or both? Policies and institutions-How these influence defining organisational roles and performance in extension organizations- Role of policies in upscaling knowledge-Role of extension in influencing policies to enable innovation.

Unit 2: Policy Advocacy and Tools

Definition of advocacy, Approaches to policy advocacy-Advising, Media campaigning, Lobbying, Activism, Information Education Communication (IEC) and Behavior Change Communication (BCC); Advocacy for Rural Advisory Services (RAS); Policy advocacy strategy.

Unit 3: Policy Analysis

Explain the meaning and use of policy analysis in decision- making; Describe different types of policy analysis- empirical, evaluative or normative policy analysis, retrospective/ prospective policy analysis, redictive/prescriptive/descriptive policy analysis; How to do policy analysis? - understand the process of policy analysis, highlight the different methods and techniques used in policy analysis, doing ethical policy analysis; Tools for policy impact- research tools, context assessment tools, communication tools, policy influence tools.

Unit 4: Policy Development Process

Policy development process: Who drives policy change?: National Governments, Donors, Civil Society-varied experiences: Understanding the environment and key actors in policy space- problem identification-policy adoption, implementation and evaluation; stakeholder mapping, identifying opportunities and barriers, mobilising financial resources; Dealing with policy incoherence: identifying contradictions and challenges in policy implementation

Block 2: Using Evidence to Influence Policy Change

Unit 1: Influencing Policy Change

Generating evidence: Role of policy research; analyzing the usefulness and appropriateness of the evidence; Using evidence in policy advocacy; Understanding your audience: analyzing channels of influence; creating alliances; identifying policy champions; Defining goals and objectives; Developing advocacy messages: Policy papers, Policy briefs, good practice notes, *etc.*: Good practices in influencing policies, Organising policy dialogues: Policy engagement strategy-Engaging with policy makers: GO and NGO experiences; Policy working groups; advisory panels; use of committees: Use of media including ICTs and social media for influencing policies. Decentralized planning.

Unit 2: Global Experience with Extension Policy

Extension policy in different countries: Explicit extension policy Vs extension as part of agriculture policy, Challenges in policy implementation: lack of capacities, financial resources, ownership, lack of stakeholder consultations: Strengthening capacities in extension to influence policies: Global Forum for Rural Advisory Services (GFRAS)'s efforts in strengthening extension policy advocacy: policy compendium, training modules, training for strengthening capacities to influence policies.

VII. Practicals

- Analysis of country/state level agricultural/extension policy to understand the policyintentions from strengthening EAS
- Analysis of extension policy of other countries: policy intentions, processes adopted in development of the policy and mechanisms of policy implementation
- Interview key policy actors in EAS arena at the state/national level (eg: Director of Agriculture, Director of Extension in SAU, Chairman/Managing Director of Commodity Board. Member Agriculture, State Planning Board) to explore policy level challenges in EAS
- Identify what evidence policy makers look for from extension research? Is the evidence available? If so what form? (Reports, Briefs etc), If not, develop a plan
- Explore how different stakeholders influence policies (eg: policy advocacy of prominent NGOs, private sector and public sector) -What mechanisms and tools they use
- Identify policy level bottlenecks that constrain effective EAS delivery at the district level- Eg: Issues around linkages between KVK and ATMA; inter-departmental collaboration; public private partnerships; joint action etc.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's book/Publication review
- Student presentation
- Group work
- Student's interview of key policy makers
- Case analysis
- Guest lectures
- Review of policy documents
- Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the role of policies in shaping performance of extension
- Understand how to generate and communicate policy relevant evidence
- Critically evaluate extension policies in different countries
- How to engage in policy advocacy.

X. Suggested Reading

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- Amosa, MDU. 2018. *Policy Analysis and Engagement Toolkit.* A guide for Pacific Non-government Organizations in the Fisheries Sector.WWF. http://d2ouvy59p0dg6k.cloudfront.net/downloads/policy_analysis_toolkit_quality.pdf
- Anonymous.N.d**.** *Policy analysis*. http://www.egyankosh.ac.in/bitstream/123456789/25760/1/Unit-19.pdf
- Anonymous. N.D. *Policy analysis*. https://web.csulb.edu/~msaintg/ppa670/670steps.htm
- Bardach E. *A Practical Guide for Policy Analysis The Eightfold Path to More Effective Problem Solving* Fourth Edition. Sage Publications. CQ Press. http://dlib.scu.ac.ir/bitstream/Ebook/32773/2/9781608718429.pdf
- Cairney P. 2015. *Chapter 2: Policymaking in the UK: What is Policy and How is it Made?. Policy and Policymaking in the UK.*
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Organization of the United Nations, Rome. http://www.fao.org/publications/policy-guidance-series/en/

- FOS. 2006. *Tracking the Impact of Policy Strategies in Conservation Work. Foundations of Success.* Prepared for The Nature Conservancy's Global Conservation Approach Team.
- https://www.cbd.int/doc/pa/tools/Tracking%20the%20Impact%20of%20Policy%20 Strategies% 20in%20Conservation%20Work%20.pdf
- GFRAS. 2018. *RAS Policy Compendium.* Global Forum for Rural Advisory Services, Switzerland. http://compendium.g-fras.org/
- GoI. 2011. *Report of the Working Group on Agricultural Extension for Agriculture and Allied Sectors for the Twelfth Five Year Plan* (2012-17), Section V-Recommendations IV,73-74. http://planningcommission.gov.in/aboutus/committee/wrkgrp12/agri/wg_agriextn.pdf
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- IFAD. 2017. *Country-level policy engagement in IFAD Guide book.* International Fund for Agricultural Development. https://www.ifad.org/documents/38714170/39144386/CLPE_book_170412_W.pdf/a203813d- 8918-43ac-a94c-ad700bcca036
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I. Course Title : Methodologies for Social and Behavioural Research

II. Course Code : EXT 602

III. Credit Hours : 2+1

IV. Why this course?

In general, social and behavioural science research plays a crucial role in the professional development in a subject domain, through advancing knowledge and developing working modalities and standards. Precisely, the empirical research helps to develop robust and outcome focused working strategies, processes and models to enable the professionals to maximise their efficiency. This course on advanced social science research caters to the need to equipping the scholars with essential skills in conducting high quality research which helps them to design working strategies, processes and models for professional development.

V. Aim of the course

This course aims to equip the doctoral students to conduct outcome-oriented social and behavioural science research and to develop sound field focused extension strategies and models with adequate replicability, while advancing knowledge on processes governing success of those strategies. The focus of the course is on equipping the scholars with advanced capacities in conducting systematic, objective and outcome oriented research by applying state-of-art methods and tools at every stage of research from planning to publishing.

The course is organized as follows:

No	Blocks	Units
1.	Advanced methods for improving quality of research data	1. Measurement Properties of Research Instruments 2. Threats to Data Quality
2.	Scales, indexes and tests	1. Scales, Indexes and Tests-1 2. Scales, Indexes and Tests-2
3.	Emerging research approaches and designs	1. Qualitative Research Methods 2. Emerging Approaches
4.	Utilising research outputs	1. Publishing Research 2. Ethics in Extension Research

VI. Theory

Block 1: Advanced Methods for Improving Quality of Research Data

Unit 1: Measurement Properties of Research Instruments

Measurement properties – Dimensionality, reliability and validity; Dimensionality unidimensionality and multidimensionality, Methods of assessing dimensionality, Formative and reflective constructs; Validity - Importance, Internal validity - face validity; content validity, Substantive Validity, Structural Validity; External validity - Convergent and Discriminant Validity, known-group validity, Criterion-Related Validity, Consequential Validity, nomological validity; Methods of assessing various forms of validities – Judges rating, Lawshe's Content Validity Ratio, Item-objective congruence index; latent variable method; Reliability - Internal consistency reliability - Split-Half, Cronbach alpha; Temporal Stability reliability - test-retest method; Interrater Consistency and Consensus – inter rater reliability and interrater agreement; Alternative Forms or parallel forms reliability – Reliability of difference - Factors Affecting the Validity and Reliability of Test Scores; Generalizability Theory

Unit 2: Threats to Data Quality

Errors and biases; Errors – Meaning and sources; Types - Sampling error, Non- sampling or measurement error and Processing error – Meaning, causes; Effects of errors and biases on data quality; Bias in behavioural research – Meaning, causes, Types – Respondent and researcher biases; Methods of reducing errors and biases in surveys, questionnaires, personal interviews, focus groups and online methods

Block 2: Scales, Indexes and Tests

Unit 1: Scales, Indexes and Tests-1

Approaches to measurement and scale development - Classical test theory. Formative or index models, The C–OAR–SE approach and Item Response Theory; Item analysis in Classical test theory – item difficulty and item discrimination; Scoring performance in scales and tests – meaning, types and methods; Scale development strategies – deductive and empirical; Stimulus-centred scales – method of equally appearing intervals, paired comparison, Person scaling – Q methodology; Subject- centre scales – The Likert scale and Semantic Differential.

Unit 2: Scales, Indexes and Tests-2

Steps in constructing a multi-dimensional scale using confirmatory factor analysis,; Response scales - Guttman's scalogram analysis and The Rasch method; Indexes–Meaning, types, importance; Similarities and differences with scales, Methods of constructing indexes; Common indexes used in extension. Measurement invariance–Meaning, types, methods of assessing measurement invariance. Tests – meaning, types, importance; steps in conducting various tests – knowledge test

Block 3: Emerging Research Approaches and Designs

Unit 1: Qualitative Research Methods

Qualitative methods – Meaning; Types – Ethnography, Grounded theory, Phenomenology, Ecological psychology, Discourse Analysis; Observational research; Case study research – Sampling and sample size; Data collection methods - In- depth interviews, Focus groups, Direct observation, Record review; Content analysis; Unobtrusive Measures; Projective and semi-projective techniques; Selecting right qualitative method – Strengths and limitations of qualitative research; Analysis and interpretation of qualitative research data; Research synthesis – meaning, importance, methods; Systematic reviews and meta analysis – meaning, steps, and applications; Policy research

Unit 2: Emerging Approaches

Mixed methods research – meaning, purpose, types and applications; Participatory research – Meaning, importance, types, methods and tools and applications; Action research – Meaning, importance, Principles, Types, Steps in conducting action research, application in behavioural sciences. Social Network Analysis – Meaning, importance, types, steps in social network analysis, applications; Advanced methods of measuring perception and beliefs. Fuzzy logic; Multi criteria decision making, analytical hierarchy approach.

Block 4: Utilising Research Outputs

Unit 1: Publishing Research

Scholarly communication process; Research reports – Meaning, types, contents; Presentations – Meaning, types, principles of good presentation - Tell 'Em" and KISS 'Em" principles; Research publications – meaning, importance, types; Guidelines for preparing research papers - Peer review process, citation styles; Open access publishing; Publishing in social media. Software in academic writing.

Unit 2: Ethics in Extension Research

Ethics in conducting behavioural research; Human subject research – Meaning, history, and ethical guidelines; Ethical aspects of collecting and using Indigenous knowledge and farmers technologies; Ethical practices in publishing; Plagiarism – meaning, sources, Identifying and correcting plagiarism in a research paper using anti-plagiarism software

VII. Practicals

- Practice in developing research instruments
- Methods of assessing measurement properties of research instruments -dimensionality, reliability and validity
- Hands-on exercises in minimising errors and biases
- Hands-on experience in constructing tests, scale and indexes
- Practice in summated scale development using confirmatory factor analysis
- Hands on experience in assessing measurement invariance
- Practicing and collecting data using participatory tools and techniques, analyzing and interpreting qualitative data
- Hands-on experience in writing systematic review using meta-analysis
- Field practice in conducting action research
- Practical experience in writing research paper
- Hands on exercises using software for qualitative data analysis
- Practice in detecting and correcting plagiarism using software

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group work
- Guest lectures
- Research report (Writing)

IX. Learning outcome

- The scholars should develop critical skills in conducting systematic and objective research by using robust methods while minimising biases and errors
- The students should intelligently choose and apply advanced methods and tools at every stage of research and execute them in a objective way by managing the actors and processes effectively
- The students should develop expertise in designing tests, scales and

indexes along with other tools to measure the socio-psychological processes at individual, group and community levels

X. Suggested Reading

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I. Course Title : Technology Commercialisation and Incubation

II. Course Code : EXT 603

III. Credit Hours : 2+1

IV. Why this course?

The technology commercialisation and incubation is an emerging area which links technology development, transfer and commercialisation processes with entrepreneurship development. Technology commercialisation aims to realize the value of agricultural technologies developed at the research establishments, by maximising their utility to stakeholders. With the increasing awareness of protecting and commercialising the Intellectual Property Resources (IPR) in the free market economy, there is a need to understand the organic relationship between protection and commercialisation IPR, and entrepreneurship development.

V. Aim of the course

This course is aimed to develop a critical understanding among extension students about how the technology commercialisation process is linked to IPR management and entrepreneurship development.

The course is organized as follows:

No	Blocks	Units
1.	Technology commercialisation and the modern context	1. Basics of Technology Commercialisation 2. Nature of Agricultural Technology 3. Basics of Technology transfer and commercialization
2.	Intellectual Property Resources (IPR) Management	1. Overview of Intellectual Property Resources 2. Systems for protecting IP 3. Management of IPR 4. Protection and Management of Biological Resources 5. Protection, Management and Commercialisation of Grass root and Farmers Innovations, Traditional and Indigenous Knowledge 6. Geographical Indications (GI) and Appellation of Origin 7. Genetically Modified Organisms (GMO), Agriculture and Biosafety
3.	Technology commercialisation	1. Technology Assessment and Refinement 2. Technology Valuation 3. Technology Commercialisation Strategies 4. Scaling up of Technologies 5. Technology Licensing 6. Technology Takers and Entrepreneurship 7. Policy Support for Technology Commercialisation and

		Entrepreneurship Development
4.	Technology Incubation	1. Basics of Technology Incubation 2. Technology Incubation in India
5.	Technology promotion and essential skills for technology	1. Technology Promotion 2. Dealing with Entrepreneurs, Agripreneurs commercialisation and Other Stakeholders
6.	Emerging approaches in technology commercialisation and incubation	1. Technology Scouting

Block 1: Technology Commercialisation and the Modern Context

Unit 1: Basics of technology commercialisation

Technology - Definition, functions, process of technological advancement – invention, discovery, innovation and technology; types of innovation - Basic research, breakthrough innovation, disruptive innovation and sustaining Iinnovation; Technology transfer and commercialisation

Unit 2: Nature of Agricultural Technology

Agricultural technology – meaning, types; technology generation system; technology life cycle

Unit 3: Basics of Technology transfer and commercialisation

Technology transfer Vs Commercialisation; Technology commercialisation process– elements, models, systems and processes; Technology transfer model – research, disclosure, development and commercialisation

Block 2: Intellectual Property Resources (IPR) Management

Unit 1: Overview of Intellectual Property Resources

Introduction to IPR; Overview & Importance; Genesis; IPR in India and IPR abroad; Patents, copyrights, trademarks & trade secrets, geographical indication, industrial design; Emergence of IPR Regimes and Governance Frameworks - Trade-Related Aspects of Intellectual Property Rights (TRIPS), Convention on Biological Diversity (CBD), Cartagena Protocol, International Union for Protection of New Plant Varieties (UPOV), and BIMSTEC.

Unit 2: Systems for Protecting IP

IPR protection laws and systems – National IPR Policy; and IPR laws; procedures for filing IP protection; Systems of IP protection and management in agricultural universities and research institutions and also by stakeholders.

Unit 3: Management of IPR

Mechanisms of IPR Management – Institutional arrangement, IP Management processes – invention disclosure; IP portfolio management; Infringement management.

Unit 4: Protection and Management of Biological Resources

Introduction; National Biodiversity Act (2002); Protection of Plant Varieties and Farmers Rights Act (2001); Guidelines for registration and transfer of biological resources; Farmers rights; Mechanisms of documenting/ collecting, protecting and commercialising farmers varieties and other biological resources; National Biodiversity Authority, PPVFRA and other agencies involved in management of biological resources in India; Access to Genetic Resources and Sharing of Benefits.

Unit 5: Protection, Management and Commercialisation of Grassrootand Farmers Innovations, Traditional and Indigenous Knowledge

Traditional and Indigenous Knowledge, Grassroot and Farmers Innovations – Meaning, forms and importance; Systems of documentation, registration, protection and commercialisation. Documentation of traditional indigenous knowledge - Traditional Knowledge Digital Library (TKDL), Community Biodiversity Registers (CBRs), People's Biodiversity Registers (PBRs), Plant Biodiversity Register, andHoneybee Network.

Unit 6: Geographical Indications (GI) and Appellation of Origin

Geographical indications and appellation of origin – meaning, origin; Geographical Indications of Goods (Registration and Protection) Act (1999); Documentation, registration and commercialisation of GI protected materials and processes.

Unit 7: Genetically Modified Organisms (GMO), Agriculture and Biosafety

The Global Concerns on Use of Genetically Modified Organisms in Food and Agriculture; The Cartagena Protocol on Bio-safety; Regulation of GMO in India - Recombinant DNA Advisory Committee (RDAC), Institutional Bio-safety Committee (IBSC), Review Committee on Genetic Manipulation (RCGM), Genetic Engineering Approval Committee (GEAC), State Bio-safety Coordination Committee (SBCC) and District Level Committee (DLC). Laws and Acts for regulation of GMO - Guidelines for Research in Transgenic Plants, 1998; Seed Policy, 2002; Plant Quarantine Order, 2003; Regulation for Import of GM Products Under Foreign Trade Policy, 2006; National Environment Policy, 2006

Block 3: Technology Commercialisation

Unit 1: Technology Assessment and Refinement

Meaning; Importance; Approaches and methods of assessment and refinement of various technologies – stakeholder oriented approaches including participatory technology assessment and refinement; assessment and refinement of traditional and indigenous knowledge and grassroot innovations.

Unit 2: Technology Valuation

Returns to investment; IP Valuation-Oxford context, IP Valuation methods - Cost approach; Income approach - Discounted Cash Flow, Risk-Adjusted Net Present Value, Net Present Value with Monte Carlo Simulation and Real Options Theory; Market approach - Industry Standards Method, Rating/Ranking Method, Rules of Thumb Approach and Auction Method; Hybrid approaches- Technological Capability; Royalty rate method.

Unit 3: Technology Commercialisation Strategies

Meaning- approaches for technology commercialisation – technology scaling up, technology licensing, handholding, agripreneur development, technology business incubation.

Unit 4: Scaling up of Technologies

Meaning, types and stages of technology scaling up; mechanisms.

Unit 5: Technology Licensing

Meaning and types - Procedures of licensing, preparing licensing documents; Management of technology licensing process.

Unit 6: Technology Takers and Entrepreneurship

Meaning; types of technology takers; Technology Taking as a Strategy; Types of entrepreneurship – agripreneurs, startups, small businesses, Producer Organizations, Self Help Groups, Clusters and other forms of entrepreneurship.

Unit 7: Policy support for Technology Commercialisation and Entrepreneurship Development

Policy support for entrepreneurship development in India - National Policy on Skill Development and Entrepreneurship and other polices; Government of India Support for Innovation and Entrepreneurship – Startup India, Make in India, Digital India, Atal Innovation Mission and others; Entrepreneurship policy and schemes at different states of India; Organisations promoting entrepreneurship in India

Block 4: Technology Incubation

Unit 1: Basics of Technology Incubation

Meaning, functions and types; stakeholder oriented incubation process – Livelihood incubation, village incubators

Unit 2: Technology Incubation in India

System of technology incubation- incubation process; its effectiveness; Managing profit oriented and non-profit incubators; Schemes for promoting incubators in India

Block 5: Technology Promotion And Essential Skills For Technology Commercialisation

Unit 1: Technology Promotion

Technology promotion – meaning, types, business meetings, scientist-industry/ entrepreneur meets, technology conclave, business plan competition, farmers fairs, technology shows

Unit 2: Dealing with Entrepreneurs, Agripreneurs and Other Stakeholders

Business communication; business etiquette; business networking

Block 6: Emerging Approaches in Technology Commercialisation and Incubation

Unit 1: Technology Scouting

Technology scouting and innovations in technology incubation

VI. Practicals

- Understanding the technology commercialisation process – Visit to Technology Commercialisation Unit of ICAR Institute/ Agricultural University
- Understanding the IPR protection practices – Visit to Patent Attorney office

- Hands-on experience in drafting IPR application – Patent/Copyright/ Trademark
- Understanding protection of biological resources including plant varieties – Visit to PPVFRA Branch office/ ICAR Institute or Agricultural University involved in plant variety protection
- Documenting traditional and indigenous knowledge – Field experience in using various protocols of using traditional and indigenous knowledge
- Protecting unique local goods through Geographical Indications – Hands on experiences in documenting and registering geographical indications
- Technology assessment/ validation of traditional and indigenous knowledge – QUIK and other methods
- Hands on experience in technology valuation
- Hands on experience in technology licensing process including drafting agreements
- Understanding the Technology Business Incubation – Visit to Agri Business Incubator or Technology Business incubator
- Hands on experience in planning and organising technology promotion events
- Hands on experience in various techniques in business communication and business etiquette

VII. Teaching methods/activities

- Lecture cum discussion
- Cases
- Class exercises
- Assignment (Reading/Writing)
- Student's book/Publication review
- Group presentation

VIII. Learning outcome

At the end of the course the students are expected to develop competencies in:

- Enabling stakeholders to protect and manage their IPR
- Managing IPR to maximise their value realisation through commercialisation, and
- Providing mentoring and handholding support to agripreneurs, rural entrepreneurs, start-ups, Farmer Organisations and other forms of entrepreneurs through incubation

IX. Suggested Reading

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I. **Course Title : Educational Technology and Instructional Design**

II. **Course Code : EXT 604**

III. **Credit Hours : 2+1**

IV. **Why this course?**

Technology, digital media and mobile access have drastically changed how people learn. And the field of education is rapidly becoming a dynamic opportunity for interactive instruction. Today's curriculum developers and instruction designers, especially in the extension and RAS ecosystem, need to equip themselves with the continuous developments in both theory and practice of instructional design so as to create satisfying learning experiences. Similarly, knowledge and skilful use of social media and disruptive technologies like internet of things (IOT), augmented reality, artificial intelligence, etc. makes this course essential for professionals who are expected to act as harbingers of change.

V. **Aim of the course**

The aim is to develop knowledgeable, responsive and effective teachers committed to educating diverse group of learners in a dynamic extension landscape. This course will help the learners to appreciate the role of technology in learning and how it can be integrated into instructional design to create engaging learning experience in both classroom and online learning environment. The course also aims to prepare the students as competent professionals employable in the extension and RAS providers both as specialised researchers as well as designers.

The course is organized as follows:

No	Blocks	Units

1.	Educational Technology Technology	1. The Landscape of Educational and Instructional Design 2. Theories of learning 3. Technology Enabled Learning
2	Instructional Design	1. Theories of Instruction 2. Creating Instruction 3. Instructional Strategies 4. Evaluating Instruction 5. Trends in Instructional Design

VI. **Theory**

Block 1: Educational Technology

Unit 1: The Landscape of Educational Technology and Instructional Design

Understanding various terms - educational technology, instructional design, instructional systems design, curriculum design, pedagogy, andragogy; brief overview of the origin and evolution of ET and ID as theory and practice; what is the relevance of ET and ID relevant in extension and rural advisory services? Extensional professionals as instructional designers and architects of the learning experience

Unit 2: Theories of Learning

What is learning? Critical overview of Behaviorism, Cognitivism, Constructivism and Complex learning theories; instructional designers and learning theories; types of learning or learning domains- Bloom's taxonomy of the cognitive domain, Krathwohl and Bloom's affective domain and Simpson's psychomotor domain.

Unit 3: Technology Enable Learning

What is the role of technology in education? Digital media, new tools and technology; Open and distance Learning (ODL); Online Education - Synchronous and Asynchronous learning models; eLearning, Massive Open Online Courses - SWAYAM, Open Education Resources (OERs), Course CERA, EduEx, CoL, RLOs; digital education and its applications in higher agricultural education; Smart classrooms and Campuses, Web-based remote laboratory (WBRL); Integrating media and digital tools into ID; types and implications of disruptive technologies for higher education and extension; Augmented learning; Adaptive learning; meaning, features and good practices in using open source Learning Management Systems (Moodle); Quality assurance and certification in e-learning.

Block 2: Instructional Design

Unit 1: Theories and Models of Instruction Howard Gardner's Theory of Multiple Intelligences, David Kolb's Learning Cycle, Albert Bandura's

Social Learning Theory, Rand Spiro's Cognitive Flexibility Theory and its Application in eLearning, Wlodkowski's Motivational Framework for Culturally Responsive Adult Learning; ADDIE Model, Dick and Carey Model, SAM Model, Bloom's Taxonomy; integrating the theories of instruction into the practice of ID in extension and RAS ecosystem.

Unit 2: Creating Instruction

Overview of planning, designing and implementing the curricula and learning experiences; Needs analysis - meaning, approaches and steps; Task and content analysis - meaning, approaches, steps and techniques (topic analysis, procedural analysis, and the critical incident method); Learner analysis – meaning, importance and approaches, relevance of Maslow's Hierarchy of needs and learning styles, captive audience vs. willing volunteers, universal vs. user-centered design, learner analysis Procedures; Writing learning objectives: meaning of learning goal and learning objectives; ABCDs of well-stated objectives; Setting goals, translating goals into objectives; Contextualising ADDIE process within the extension learningenvironment

Unit 3: Instructional Strategies

Organizing content and learning activities - scope and sequence of instruction; Posner's levels of organizing (Macro, Micro, Vertical, and Horizontal) and structures of organizing (content vs. media) instruction, Gagne's events of instruction, Edgar Dale's Cone of Experience; Methods of Delivery- classroom teaching, programmed instruction, synchronous and asynchronous modes of distance education; Changing role of a teacher in classroom and teaching competencies

Unit 4: Evaluating Instruction

Meaning of assessment, measurement and evaluation; Developing learner evaluations and their reliability & validity; Assessment techniques for measuring change in knowledge, skill and attitude of learners - Objective Test Items, Constructed-Response Tests, Direct Testing, Performance Ratings, Observations and Anecdotal Records, Rubrics, Portfolios, Surveys and Questionnaires, Self- Reporting Inventories, Interviews; Conducting learner evaluation pre-, during and post-instruction; Formative and summative evaluation- meaning, approaches and steps; Evaluating learner achievement and the instructional design process; Evaluating the success of instruction; Performance appraisal of teachers

Unit 5: Trends in Instructional Design

Alternatives to ADDIE model - Rapid prototyping and constructivist ID, reflections on instructional design as science and as an art; Relating ID models and process in extension learning environment; Political economy of higher education in developed and developing countries; University assessment and rating methods, returns from agricultural higher education; Research in education and instructional design.

VII. **Practicals**

- Exercises on preparation of the analysis report that includes the task/content analysis and learner analysis and the design plan includes learning objectives and corresponding instructional strategies and assessment items
- Prepare course outline and lesson plan with an appreciation for diverse learning styles based on temperament, gender, and cultural/ethnic differences and delivera lecture for UG/PG students
- Assessing learning styles through Barsch and Kolb inventories
- Development and testing of survey instruments for evaluating learning outcomes/ competencies of students
- Development and testing of survey instruments for performance appraisal / competency assessment of teachers.
- Design an online e-learning module on a topic of interest as a capstone project - integrate and apply the knowledge and skills gained from the course for creating an effective learning experience for a target audience
- Designing and developing a theme based knowledge portals
- Exercises on designing an online course using open source LMS like moodle orEdX
- Select and evaluate or design for social media
- Prepare a short research paper on recent theories and models of instructional design
- Interview an instructional designer of your choice and prepare a synthesis report about what job roles he/she perform, what ID processes does he or she use, challenges faced
- Develop a prototype for one of the lessons in your design plan using PowerPoint or a website builder such as Weebly to create the screens integrating multimedia content and various functionalities
- Field visit to a virtual learning / augmented learning labs, e-learning labs, distance learning centres, etc.
- Hands-on practice with video-editing software, web conferencing and video conferencing solutions

VIII. **Teaching methods/activities**

- Lectures & videos
- Individual and group assignments
- Group discussion and debating
- Enactive learning exercises
- Case studies / Case analysis
- Storyboarding
- Guest lectures
- Field visits
- Capstone project

- Prototype development

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Develop a critical understanding of concepts of learning and education within the context of agricultural development
- Relate and apply learning theories and models to the development, design and evaluation of courses utilizing educational technology and instructional design
- Hone their skills to take up research work in analysing and evaluating different learning systems, teaching-learning environments, competencies and learning outcomes
- Find placement opportunities in the industry for job profiles such as e-learning specialist, training officer, curriculum developer, instructional designer, education consultant, etc.

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- **Websites**
- e-Learning Industry– https://elearningindustry.com/
- Instructional Design Central– https://www.instructionaldesigncentral.com/ Instructional Design– http://www.instructionaldesign.org/theories/ International Society for Educational Technology– https://www.isfet.org/courses/ Educational Technology– https://educationaltechnology.net/
- AESA-Agricultural Extension in South Asia– http://www.aesanetwork.org/ GFRAS-Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

I. **Course Title : Risk Management and Climate Change Adaptation**

II. **Course Code : EXT 605**

III. **Credit Hours : 2+1**

IV. **Why this course?**

Present agriculture and allied sectors India face tremendous challenges on multiple fronts. Agrarian distress and the climate change impacts together pose grave dangers to food, nutritional and ecological security. As change agents, extensional professionals in particular and agricultural graduates in general need to quip themselves with knowledge and skill sets required to navigate the climate change scenario so as to help reduce risk and vulnerability. Hence, this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of risks management and climate change adaptation with reference to Indian agriculture. This course will approach the subjects from a multidisciplinary perspective - technical, socio-economic, political, financial, and regulatory. It aims to equip students to identify, evaluate and evolve ways to address (mitigate and manage) risks and climate change.

The course is organized as follows:

No	Blocks	Units
1.	Risk Management in Agriculture	1. Understanding Risk and Distress 2. Managing Risk and Distress in Agriculture 3. Extension Professionals and Risk management
2.	Adapting to Climate Change	1. Introduction to Climate Change Science 2. Introduction to Climate Change Adaptation and Mitigation 3. Climate Smart Agriculture and 4. Extension Advisory Services

VI. Theory

Block 1: Risk Management in Agriculture

Unit 1: Understanding Risk and Distress

Introduction to risk, risk management, uncertainty, sensitivity and distress, general risk theory, risk analysis methods, risk perception and decision making, indicators of risk and distress in agriculture – identification, selection and assessment, understanding the agrarian distress in Indian agriculture, sources of distress in Indian farming -changing farm size, land use, cropping patterns, pricing policy, markets and terms of trade, Typology of crisis in agriculture; Droughts, floods and Indian agriculture, distress and farmer suicides - causes and socio-economic consequences.

Unit 2: Managing Risk and Distress

Ways to reducing/managing risk and distress in Indian agriculture; crop and life insurance; Developing support systems; Planning, implementation and evaluation of risk/distress management programs; Institutional frameworks for risk and disaster management - NDMA & SDMAs; Developing District Agriculture Contingency Plans; Risk management by diversification; Good practices and lessons from other countries; Responses of government, non-government and extension system to agrarian crisis; National Farmers Policy.

Unit 3: Extension Professionals and Risk Management

Understanding social-psychological and behavioural dimensions of farmers under risk/distress; Risk perception and communication; Helping farmers manage farm level risks - mobilising resources, linking with markets, strengthening capacities; Working with village level risk management committees; Operational skills for preparing contingency and disaster management plans; Institutional and extension innovations in managing risk and distress; Policy and technological preferences for dealing with drought and flood.

Block 2: Adapting to Climate Change

Unit 1: Introduction to Climate Change Science

Basic concepts of and terms in climate change science; impacts of climate change; anthropogenic drivers of climate change, climate change and Indian agriculture; climate adaptation vs. disaster risk reduction; anticipated costs of adaptation; climate change and poor; overview of UNFCCC framework and institutions, Kyoto Protocol and beyond; India's National Action Plan on Climate Change and National Mission on Strategic Knowledge on Climate Change; National Coastal Mission, Institutional arrangements for managing climate change agenda.

Unit 2: Introduction to Climate Change Adaptation and Mitigation

Introduction to climate change adaptation, Conducting a vulnerability assessment (CVI and SEVI frameworks), Identifying and selecting adaptation options; Global, national and state level initiatives and plans to support climate change adaptation, private sector and civil society initiatives and activities; Mainstreaming climate change adaptation into development planning, financing climate adaptation and budgetary allocations for programmes, gender and climate change adaptation, agricultural development programmes and strategies towards climate change adaptation and mitigation, community based and ecosystem based adaptation strategies, preparing evidence based intervention plans for vulnerability reduction at micro and macro-levels.

Unit3: Climate Smart Agriculture (CSA) and Extension &Advisory Services

Climate smart agriculture; Developing climate smart and climate resilient villages; Stakeholders and determinants involved in climate smart agriculture; Climate smart agriculture and EAS; Innovative extension approaches used in CSA; Climate information services, farmers perceptions about climate change; Farm and household level manifestations and adaptation strategies; Barriers and limits to adaptation; Farmers feedback on performance of extension methods; Skills, competencies and tools required for extension professionals at different levels and development departments in up scaling CSA. CRA, documentation of indigenous adaptation strategies of farmers.

VII. Practicals

- Hands-on practice in using risk assessment/analysis tools
- Case studies on risk / distress assessment in agriculture -Indian and global
- Lessons / experiences from NICRA Project in agriculture and allied sectors
- Developing criteria, indicators and indices for assessment of risk, vulnerability and resilience
- Hands on practice on use of vulnerability and risk assessment tools and techniques
- Case studies on success stories of climate change adaptation and community based initiatives
- Developing district and village level intervention plans for climate change adaptation
- Field visits to State Disaster Management Authority
- Case studies on climate smart agriculture / villages from India and world
- Case studies on impact assessment of crop insurance programs, disaster management programs
- Capstone project on documenting ITKs and local practices related to reducing risk / climate resilience agriculture

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's book/Publication review
- Student presentation
- Group work
- Student's interview of key policy makers
- Case analysis and case studies guest lectures
- Review of policy documents

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the scientific foundation of risk management and climate change science and relate the key learning to the job of an extension professional
- Utilise methods and tools for risk and climate related vulnerability assessments and adaptation strategies in the context of Indian agriculture / farming scenario
- Utilise material in scientific publications relevant for risk management

and climate change adaptation and critically reflect on their benefits and limitations for decision making

X. Suggested Reading

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GFRAS-Global Forum for Rural Advisory Services– http://www.g-fras.org/en/ **AESA-**Agricultural Extension in South Asia– http://www.aesanetwork.org/ **NICRA-**National Innovations in Climate Resilient Agriculture–

http://www.nicra-icar.in/nicrarevised/

CRIDA-Central Research Institute for Dryland Agriculture– http://www.crida.in/ **UNCC: Learn-** UN Climate Change Learning Partnership– https://www.uncclearn.org/ **DST-** Department of Science and Technology- Climate Change Programme, GoI–

http://www.dst.gov.in/climate-change-programme

I. Course Title : Livelihood Development

II. Course Code : EXT 606

III. Credit Hours : 1+1

IV. Why this course?

One of the aims of extension work is to enhance and expand the sustainable livelihood opportunities for individuals in a society. For this a thorough understanding of the different aspects of livelihood and its interface with nature becomes imperative. Resource poor farmers and the socially and politically weaker sections of the society currently face several challenges in expanding their livelihoods. Keeping these in view, the course has been designed to provide a theoretical framework for understanding of the basic concepts, definitions and approaches related to 'livelihood', 'vulnerability' 'institutional processes', and 'development and policies' pertaining to livelihood development in India.

V. Aim of the course

- To develop an understanding on the concept of livelihood and its various forms
- To acquaint the students regarding the various alternative approaches that hasbeen adopted to support livelihoods
- To familiarize the students to some of the methods, tools and techniques they canutilize to design livelihood interventions
- To expose the students to the context, especially the economic models and policyenvironment that guides the livelihood choices
- To equip students to work in multidisciplinary teams and engage at multiple levels on livelihood issues

The course is organized as follows:

No	Blocks	Units

1.	Understanding of Livelihood	1. Concept of Livelihoods 2. Livelihood Challenges
2.	Livelihood Analysis	1. Livelihood Frameworks 2. Designing Livelihood Intervention and Promotion
3.	Livelihood Augmentation	1. Pathways for LA

VI. **Theory**

Block 1: Understanding of Livelihood

Unit 1: Concept of Livelihoods

Basic concepts of livelihood and development, Types of development-Immanent/ inherent and interventionist/ intentional; Why promote livelihood; Livelihood intervention: definition, types-spatial, segmental, sector –sub-sector; Systemic view of Livelihoods, Understanding rural livelihoods-farm, non-Farm, and off farm; Linkages with farm and off-farm livelihoods; Economic models

Unit 2: Livelihood Challenges

Livelihood Challenge- Political economy of Livelihoods, Issues of access to farm and non-farm livelihoods; Livelihoods from a Gender Perspective-Feminization of agriculture/ poverty, women in the unorganized sector, the issue of unpaid and informal work; Livelihood Coping Mechanism-Climate Change and Livelihoods; Livelihoods and Disasters.

Block 2: Livelihood Analysis

Unit 1: Livelihood Frameworks

Sustainable Livelihoods Approaches (SLAs)-Definition and origins of SLA; Assets or capitals and capabilities in SLA and its linkage to the other capitals: Physical, Social, Economic, Human, Natural; Vulnerability Assessment- Shocks, trends, seasonality; Policies, institutional context and processes; Conceptual Frameworks- DFID, CARE, UNDP, OXFAM, BASIX livelihood triad, Nine square Mandala or Rural Livelihood System's Framework, etc.; Past, Present and possibilities for the future of the SLA, critiques of the approach

Unit 2: Designing Livelihood Intervention and Promotion

Designing a suitable livelihood intervention-Observing and understanding the local economy; Selecting livelihood activities suitable for the poor in the area; Deciding on the interventions. Livelihood promotion approaches-Poverty and livelihood: Approaches and programs in India; Livelihood and a rights based approach- MGNREGA and its critique; Livelihood and a social capital based approach: NRLM

Block 3: Livelihood Augmentation (LA)

Unit 1: Pathways for LA

Basic concepts; Pathways: a) Entrepreneurial strategies for LA; b) NRM based intervention; c) Market based interventions including value-chain analysis; d) ICT based interventions; e) Livelihood and allied agriculture (dairy, poultry, Goatery, etc.) based livelihood; f) Forest based livelihoods vis a vis livelihood protection and promotion: Contribution of NTFP in supporting rural livelihoods

Note: Block 'A' and 'B' is theoretical; Block 'C' should be covered in the form practical's supported by few classroom discussion through cases

VII. Practicals

- Village stays to understand the livelihood pattern of villagers and how the other socio-economic factors affect the livelihood of people
- Visit to institutes/ universities adopted and/or nearby villages to experience the life and natural resources in rural communities-understanding of village culture, evolution, social structure, livelihood pattern, trends, governance arrangements, and the natural context (landscape layout, land use, vegetation types etc)
- Application of participatory rural appraisal skills for understanding village context; Engagement of working with rural communities and their grass-root institutions, understanding dynamics of working in a group
- Visit to different agri-business models as mentioned in the Block 'C'. Group assignments may be given to document the field experience in the form of case study of an enterprise/ entrepreneur/ members and other related stakeholders
- Development of composite livelihood index
- Biodiversity mainstreaming for livelihood augmentation

VIII. Teaching methods/activities

- Interactive lectures – by sharing in advance a reading material
- Analysis of case studies
- Audio-visual of successful/ failure models of agribusiness firms
- Guest session by field practitioners, if possible
- Group presentations by the students
- Field visit and field based individual or group assignments

IX. Learning outcome

This course will equip students with perspectives, knowledge and skills to develop a comprehensive understanding of the livelihood concepts, various forms, approaches, tools and techniques to analyze existing livelihood pattern and strategies the sustainable livelihood intervention in the rural areas.

X. Suggested Reading

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I. Course Title : Facilitation for People Centric Development

II. Course Code : EXT 607

III. Credit Hours : 2+1

IV. Why this course?

The prime aim of the agricultural extension professionals is to influence development change among the stakeholders with whom they work. In the Agricultural Innovation Systems (AIS) context, this change will happen when good relationships, networks and partnerships are formed. A new extension approach that aims at participatory and group learning as well as networking, where the extensionist acts as a facilitator is needed. It is important to inculcate the good facilitation skills by the extension professional to increase the effectiveness and impact among the agricultural extension and advisory services stakeholders.

V. Aim of the course

- To orient students on the importance facilitation
- To inspires students to understand facilitation tools to influence change at the individual, group and organisational levels
- To develop capacities in multi-stakeholder engagement, facilitation and networking

The course is organized as follows:

No	Blocks	Units

1. Introduction to Facilitation for Development	1. Facilitation for Development in the AIS 2. Principles, Attributes and Skills for Facilitation for Development
2. Facilitating change in individuals, groups and organizations	1. Realise Potential- Self- Discovery 2. Group Dynamics and Working Together 3. Organizational Change Process
3. Facilitating operational level multi-stakeholder engagements	1. Multi-Stakeholder Interactions 2. Innovation and Policy Engagement Platforms
4. Brokering strategic partnerships, networking and facilitation	1. Linkages, Partnerships, Alliances and Networking 2. Facilitating Capacity Development

VI. **Theory**

Block 1: Introduction to Facilitation for Development

Unit 1: Facilitation for development in the AIS

Facilitation for development in the AIS; Understanding facilitation for development; Importance of facilitation as a core function of extension within the Agricultural Innovation Systems (AIS)

Unit 2: Principles, Attributes and Skills for Facilitation for Development

Basic principles of facilitation for development; Desired attributes of facilitator for development- Cognitive attributes, Emotional attributes (Emotional intelligence), Social, behavioural and attitudinal attributes; Technical skills of a facilitator for development- Design processes, Facilitation techniques and tools, the art of questioning and probing, Process observation and documentation, Visualisation.

Block 2: Facilitating Change in Individuals, Groups and Organisations

Unit 1: Realise Potential- Self-Discovery

Self-discovery to realise our potentials, Tools for self-discovery, formulating a personal vision, Taking responsibility for your own development.

Unit 2: Group Dynamics and Working Together

Understanding the dynamics of human interaction, Group dynamics and power relations, Managing relationships, Shared vision and collective action, Tools for team building.

Unit 3: Organizational Change Process

Organizational change process, Organizational learning to adapt to changing environments, Enhancing performance of organizations, Leadership development, Tools for organizational change.

Block 3: Facilitating Operational Level Multi-stakeholder Engagements

Unit 1: Multi-Stakeholder Interactions

Defining stakeholders, Development of collective and shared goals, Building trust and accountability, Tools for stakeholder identification and visioning.

Unit 2: Innovation and Policy engagement Platforms

Visualising innovation platforms (IPs), Why are IPs important?, Different models of IPs for multi-stakeholder engagement, policy engagement platforms, Generating issues and evidence for policy action, Advocacy for responsive policy processes.

Block 4: Brokering Strategic Partnerships, Networking And Facilitation

Unit 1: Linkages, Partnerships, Alliances and Networking

Brokering linkages and strategic partnerships, Identification of critical links, Knowledge brokering, Creating linkages with markets, Learning alliances and networking, Coordination of pluralistic service provision within the AIS, The concept of action learning and reflective practitioners, Networking.

Unit 2: Facilitating Capacity Development

Facilitating Capacity Development-Facilitate participation and learning in development programs and projects. Virtual platforms- skills for strengthening dialogue, collaboration, shared commitment amongst diverse actors and stakeholders.

VII. Practicals

- Practicing facilitation techniques,
- Self discovery Exercises,
- Working together and interaction (task based),
- Arrangement for multi-stakeholder interactions,
- Understanding organisational change process tools and techniques,
- Case analysis on organisational change process,
- Participating with innovation platforms,
- Policy engagement platforms,
- Stakeholder analysis mapping,
- Exercises on networking skills,
- Facilitating capacity building programmes
- Facilitating virtual platforms
- Filed visit to multi-stakeholder partnership projects

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student’s Book/Facilitation Manual/Publication Review
- Student presentation
- Group work
- Student’s interview with facilitators
- Case analysis
- Guest lectures
- Review of facilitation methodologies
- Short internships

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the importance of facilitation skills and tools
- Understand facilitation and networking techniques
- Critically evaluate strategic partnerships and linkages
- How to manage group dynamics and engage multi-stakeholders and virtual platforms

X. Suggested Reading

- Anonymous. *Seeds for Change. Facilitation Tools for Meetings and Workshops.* Available https://seedsforchange.org.uk/tools.pdf
- Clarke S, Blackman R and Carter I. 2004. *Facilitation skills workbook -Training material for people facilitating small group discussions and activities using PILLARS Guides*. Tearfund, England.
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- Mind Tools. 2005. *The Role of a Facilitator-Guiding an Event through to a Successful Conclusion.* https://www.mindtools.com/pages/article/RoleofAFacilitator.htm
- Mittal N, Sulaiman RV and Prasad RM. 2016. *Assessing Capacity Needs of Extension and Advisory Services A Guide for Facilitators.* Agricultural Extension in South Asia. http://www.aesanetwork.org/assessing-capacity-needs-of-extension-and-advisory-services- a-guide-for-facilitators/
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- Villet, V V. 2015. *Motivation Theory by David McClelland*. https://www.mindtools.com/pages/article/human-motivation-theory.htm

Websites

- **MSU**–Michigan State University Extension Facilitation– https://www.canr.msu.edu/facilitation
- **TAPipedia**– Tropical Agriculture Platform–https://www.tapipedia.org/
- **CGSpace**- A Repository of Agricultural Research Outputs by CGIAR– https://cgspace.cgiar.org/handle/10568/33667
- **UMaine**– The University of Maine– https://extension.umaine.edu/community/strengthening-your-facilitation-skills/
- **GFRAS**– Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

I. Course Title : Multivariate Statistical Methods For Extension Research

II. Course Code : STAT

III. Credit Hours : 2+1

IV. Why this course?

With increasing complexity in agricultural systems, research problems in extension are becoming multi-dimensional and often influenced by the composite of biological, social and economical factors. Such complex problems require advanced analytical methods and tools derived from statistical and other decision sciences.

V. Aim of the course

This course aims to equip the students with critical skills in choosing appropriate analytical tools and interpreting the results for solving multidimensional extension research problems.

The course is organized as follows:

No.	Blocks	Units
1.	Overview of Multivariate Statistical Methods	1. Basics of Multivariate Statistical Methods (MVSM) 2. Classification and Types of MVSM 3. Selecting Appropriate MVSM 4. A Structured Approach for Building Multivariate Statistical Models 5. Basic Econometric Methods-1 6. Basic Econometric Methods-2
2.	Data preparation and cleaning	1. Missing Data Analysis and Outlier Management 2. Testing Assumptions of MVSM and Data Transformation
3.	Methods for assessing human choice/ preferences and decision-making	1. Assessing Human Preference Structures Using Conjoint Analysis 2. Assessment of Adoption of Agricultural Technologies Using Limited Dependent Variable Models 3. Multidimensional Scaling 4. Multi-criteria Decision-making
4.	Methods of assessing association and causality	1. Multiple Correlations and Multiple Regressions 2. Discriminant Analysis
5.	Methods of Grouping Objects/ Variables Based On Latent Variables	1. Principal Component Analysis (PCA) and Common Factor Analysis 2. Structural Equation Modelling (SEM) – Two Units 3. Cluster Analysis
6.	Emerging MV Statistical Methods	1. Emerging MV Statistical Methods

VI. Learning outcome

At the end of this course, the students will be able – To choose appropriate multivariate statistical methods based on research problem/ situation – To design, implement and interpret in a skilful way using SPSS.

VII. Theory

Block 1: Overview of Multivariate Statistical Methods

Unit 1: Basics of Multivariate Statistical Methods (MVSM)

What is multivariate data analysis; Basic concepts in MV – variate, measurement error; Power analysis and effect size; SPSS software.

Unit 2: Classification and Types of MVSM

Independence and dependence techniques; Factor analysis – principal component, exploratory factor analysis; Multiple correlation and multiple regression; Discriminant analysis; Logistic regression; Cluster analysis; Conjoint analysis; Multi dimensional Scaling/ Perceptual mapping; Correspondence analysis; Structural equation model.

Unit 3: Selecting Appropriate MVSM

Selection based on purpose - Dimension reduction, identifying latent variables, strength of relationship among multiple dependent/ independent variables, identifying choice and estimating their utility; etc and type of variables – metric and non-metric.

Unit 4: A Structured Approach for Building Multivariate Statistical Models

Steps in planning and conducing MVSM.

Unit 5: Basic Econometric Methods-1

Nature of regression analysis; Two variable and multivariable regression models; Linear and non-linear regression models; Estimation methods.

Unit 6: Basic Econometric Methods-2

Simultaneous-equation models; Panel data models; **Forecasting** - Time series and other models.

Block 2: Data Preparation and Cleaning

Unit 1: Missing Data Analysis and Outlier Management

Missing data - Meaning, types, methods of missing data processing, advantages and limitations, **Outliers-** Meaning, types, methods for identifying and managing outliers.

Unit 2: Testing Assumptions of MVSM and Data Transformation

Testing assumption of parametric analyses – normality, linearity, multicollinearity; Data transformation methods.

Block 3: Methods for Assessing Human Choice/ Preferences and Decision-making

Unit 1: Assessing Human Preference Structures Using Conjoint Analysis

Meaning- Importance, guidelines for selecting variables, steps in designing a conjoint experiment extension.

Unit 2: Assessment of Adoption of Agricultural Technologies Using Limited Dependent Variable Models

Meaning, importance, types – logit, probit and tobit and their variations; steps in analysis and interpretation of results, applications in extension.

Unit 3: Multidimensional Scaling

Meaning, importance and types, steps and applications in extension.

Unit 4: Multi-criteria decision-making

Meaning, importance, methods – analytical hierarchy process, Applications in extension.

Block 4: Methods of Assessing Association and Causality

Unit 1: Multiple Correlations and Multiple Regressions

Meaning, importance, types, methods of estimation, analysis and interpretation of results, applications in extension.

Unit 2: Discriminant Analysis

Meaning, types, steps in conducting discriminant analysis, Applications in extension.

Block 5: Methods Of Grouping Objects/ Variables Based On Latent Variables

Unit 1: Principal Component Analysis (PCA) and Common Factor Analysis

Meaning, importance, types of factor analysis, difference between types, steps in conducting PCA/ Common Factor Analysis, applications in extension.

Unit 2: Structural Equation Modelling (SEM) – Two units

Meaning, importance, types – confirmatory factor analysis and structural model; steps in conducting SEM, applications in extension.

Unit 3: Cluster Analysis

Meaning, importance, types – Steps; Applications in extension.

Block 6: Emerging MV Statistical Methods

Unit 1: Emerging MV Statistical Methods

Canonical correlation, partial least square (PLS).

VIII. Practicals

- Hands on experience of following methods using SPSS/ AMOS software
- Selecting appropriate MVSM
- Missing data analysis and outlier management
- Testing assumptions of MVSM and data transformation
- Assessing human preference structures using conjoint analysis
- Assessment of adoption of agricultural technologies using limited dependent variable models – logit, probit and tobit.
- Multidimensional scaling
- Multiple correlation and multiple regression
- Discriminant analysis
- Principal Component Analysis (PCA) and Common Factor Analysis
- Structural Equation Modeling (SEM)
- Cluster analysis

IX. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group work

– Guest lectures

X. Suggested Reading

- Agresti, A. 2002. *Categorical data analysis*. Second edition. New York, NY: John Wiley & Sons. Belsley, D. A. 1991. *Conditioning diagnostics: Collinearity and weak data in regression*. New York, NY: Wiley.
- Bollen, K.A. 1989. *Structural equations with latent variables*. New York: John Wiley and Sons. Burnham, K. P. and Anderson, D. R. 2002. *Model selection and multimodel inference*. New York, NY: Springer.
- Byrne BM. 2010. *Structural equation modeling with AMOS: Basic concepts, applications, and programming.* New York: Routledge.
- Chambers, J., Cleveland, W., Kleiner, B., and Tukey, P. 1983. *Graphical methods for data analysis*. Wadsworth.
- Field A. 2013. *Discovering statistics using IBM SPSS Statistics,* 4th edition. Sage, London. Greene, W. 2000. *Econometric Analysis* Fourth edition. New York, NY: Wiley.
- Hair JJF, Black WC, Babin BJ and Anderson RE. 2010. *Multivariate Data Analysis: A Global Perspective.* 7th Edition, Pearson.
- Hosmer, D. W. and Lemeshow, S. 2000. *Applied logistic regression*. Second edition. New York, NY: John Wiley & Sons
- Kelloway, K. E. 1998. *Using LISREL for structural equation modeling: A researcher's guide.* Thousand Oaks: Sage
- Long, J. S. 1997. *Regression models of categorical and limited dependent variables.* Thousand Oaks, CA: Sage
- Ray, S. 2016. *A comprehensive guide to data exploration*. https://www.analyticsvidhya.com/ blog/2016/01/guide-data-exploration/
- Sivakumar SP, Sontakki BS, Sulaiman RV, Saravanan R, Mittal R. 2017. *Manual on Good Practices in Extension Research & Evaluation*. Agricultural Extension in South Asia. http:/
- /www.aesanetwork.org/manual-on-good-practices-in-extension-research-and-evaluation/ Stokes, M. E., Davis, C. S., and Koch, G. G. 2000. *Categorical data analysis using the SAS system*. Cary, NC: SAS Institute Inc

AGRICULTURAL ECONOMICS

Course Title with Credit load M.Sc. (Ag) in Agricultural Economics

Major Courses: 20 credits

Course Code	Course Title	Credit Hours
AEC-501*	Micro Economic Theory and Applications	3 (3+0)
AEC-502*	Agricultural Production Economics	2 (1+1)
AEC-503*	Agricultural Marketing and Price Analysis	3 (2+1)
AEC-504*	Macro Economics and Policy	2 (2+0)
AEC-505*	Econometrics	3 (2+1)
AEC- 506	Agricultural Development and Policy Analysis	2 (2+0)
AEC-507*	Agricultural Finance and Project Management	3 (2+1)
AEC-508*	Linear Programming	2 (1+1)
AEC-509*	Research Methodology for Social Sciences	2 (1+1)
AEC-510	Indian Economy: History and Contemporary Issues	2 (2+0)
AEC-511	International Economics	2 (1+1)

*courses to be taken compulsorily

Minor Courses: 08 credits

a. It is suggested the student may choose at least two out of three courses listed above as part of minor courses as these are related to policy advocacy and aim to build larger understanding of the subject.

b. Further, it is suggested that the student may also opt to choose the remaining Courses from any other discipline including the disciplines of Agrl. Extensions/ ABM and are related to the research problem selected by the student.

c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/ HOD.

Course Code	Course Title	Credit Hours
AEC-512	Institutional Economics	1(1+0)
AEC-513	Natural Resource and Environmental Economics	2 (1+1)
AEC-514	Commodity Future Trading	2 (2+0)
AEC-515	Development Economics	2 (2+0)

Common Courses: 05 credits

Course Contents

M.Sc. (Ag) in Agricultural Economics

Restructured and Revised Syllabi of Post-graduate Programmes

I. **Course Title : Micro Economic Theory and Applications**

II. **Course Code : AEC-501**

III. **Credit Hours : 3+0**

IV. **Why this course?**

Markets form an integral part of the economy. They are governed by demand and supply mechanism with profit making its ultimate goal. Thus, it is imperative to expose the students towards how the markets function, their types and how the buyers and sellers behave. That will help them make correct decision when it comes to price setting and choice of product.

V. **Aim of the course**

The course envisages the concepts and principles embodying micro-economics. The economic problems, functioning of price mechanism, theory of household behaviour and consumer's demand function. Theory of firm, supply determinants, determination of price under different market structures and factor pricing (micro economic components).

VI. **Organisation of the course**

The course is organised as follows:

No	Block	Unit
1.	Introduction to micro-economics	1. Basic Concepts: A review
2.	Insight of consumer, production	1. Consumer Choice and cost involved 2. Production and Cost
3.	Overview of market	1. Market Forms 2. Factor Markets

VII. **Theory**

Block 1: Introduction to micro- economics

Unit 1: Basic Concepts: A review

Scarcity and Choice; Production possibility frontier, Positive and normative economics; concepts of opportunity cost, Demand and Supply: determinants of individual demand/supply; demand/ supply schedule and demand/ supply curve; market versus individual demand/ supply; shifts in the demand/ supply curve

Block 2- Insight of consumer, production and cost involved

Unit 1: Consumer Choice

Cardinal Utility Approach – Ordinal Utility Approach -Budget sets and Preferences under different situations – Hicks and Slutsky income and substitution effects –

Applications of Indifference curve approach – Revealed Preference Hypothesis – Consumer surplus – Derivation of Demand curve – Elasticity of demand – Demand and supply together; how prices allocate resources; controls on prices – price floorand price ceiling – applications in agriculture.

Unit 2: Production and Cost

Production functions: single variable - average and marginal product, variable proportions, stages of production. Two variables - isoquants, returns to scale andto a factor; factor prices; Technical progress; cost minimization and output maximization; Elasticity of substitution. Expansion path and the cost function

Concept of economic cost; Short run and long run cost curves; increasing and decreasing cost industries; envelope curve; L-shaped cost curves; economies of scale; revenue and expenditure, elasticity and marginal revenue; Firm equilibrium and profit.

Block 3: Overview of market

Unit 1: Market Forms

Behaviour of profit maximizing firms and the production process-Perfect competition: Equilibrium of the market. Long run industry supply, applications: effects of taxes and subsidies; Monopoly: Equilibrium; supply; multiplant firm; monopoly power; deadweight loss; price discrimination; Monopolistic Competition: Product differentiation; equilibrium of the firm in the industry-with entry of new firms and with price competition. Comparison with pure competition. Duoploy: Cournot model and reaction curves; Stackelberg‘s model, Bertrand model; Oligopoly.

Unit 2: Factor Markets

Labour and land markets - basic concepts (derived demand, productivity of an input, marginal productivity of labour, marginal revenue product); demand for labour; input demand curves; shifts in input demand curves; competitive labour markets; Economic rent and quasi rent.

VIII. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions on practises done by firms.
- Power point presentations by students.
- Exploring the agricultural market and identification of industries and their type.

IX. Learning outcome

After completion of the course the student will be able to:

- Get acquainted with the basic concepts of market functions.
- Build up vision towards how consumers makes choices and market reaches theequilibrium.
- Develop decision making skill for firms about product selections and scale ofproduction to ensure maximum profit.
- Understand about different types of markets existing in the real world, their principles and whereabouts.

X. **Suggested Reading**

- Koutsoyiannis A. *Modern Micro Economics*. Macmillan Press Ltd
- Richard A. Bilas, *Micro Economic Theory*.
- Leftwich Richard H. *The Price System and Resources Allocation*
- Allen CL. *A Frame Work of Price Theory*.

I. **Course Title : Agricultural Production Economics**

II. **Course Code : AEC-502**

III. **Credit Hours : 1+1**

IV. **Why this course?**

Production in agriculture is the outcome of the input factors involved. In this competitive and uncertain market, it is important that the farmers take the right decision about the combination of inputs that will result in higher income. Thus, as an economist it is a pre-requisite that the students understand the interaction between output and input. And work out the most effective production plan.

V. **Aim of the course**

To expose the students to develop the concept, significance and uses of production economics. To understand the relationships between factors and output. To learn how to decide the combination of inputs to be used as per the resources available. Ensure that the production process works efficiently.

VI. **Organization of the course**

The course is organised as follows-

No	Block	Unit
1.	Introduction to Production Economics	1. Concepts of production economics
2.	Factors and costs	1. Factors and theory of production 2. Concepts of costs
3.	Assessment	1. Dynamics of assessment

VII. **Theory**

Block 1: Introduction to Production Economics

Unit 1: Concepts of production economics

Nature, scope and significance of agricultural production economics- Agricultural Production processes, character and dimensions-spatial, temporal - Centrality of production functions, assumptions of production functions, commonly used forms - Properties, limitations, specification, estimation and interpretation of commonly used production functions.

Block 2: Factors and costs

Unit 1: Factors and theory of production

Factors of production, classification, interdependence, and factor substitution

-Determination of optimal levels of production and factor application - Optimal factor combination and least cost combination of production - Theory of product choice; selection of optimal product combination.

Unit 2: Concepts of cost

Cost functions and cost curves, components, and cost minimization -Duality theory – cost and production functions and its applications -Derivation of firm's input demand and output supply functions -Economies and diseconomies of scale.

Block 3: Assessment

Unit 1: Dynamics of economic assessment

Technology in agricultural production, nature and effects and measurement - Measuring efficiency in agricultural production; technical, allocative and economic efficiencies - Yield gap analysis-concepts-types and measurement - Nature and sources of risk, modeling and coping strategies.

VIII. Practical

- Different forms of production functions
- Specification, estimation and interpretation of production functions
- Returns to scale, factor shares, elasticity of production
- Physical optima-economic optima
- Least cost combination
- Optimal product choice
- Cost function estimation, interpretation
- Estimation of yield gap
- Incorporation of technology in production functions
- Measuring returns to scale-risk analysis.

IX. Teaching Methods/ Activities

- Lectures
- Assignments (Group/individual)
- Group Discussions on working out
- Power point presentations by students
- Exploring the agricultural market and identification of industries and their type.

X. Learning outcome

After the successful completion of the course the student will be able to— Understand how the factors and output interact with each other. - Work out whether the production system is working efficiently and point out the loop holes.- Apply the knowledge of costs and profits to work out the demand and supply functions. This will result into more efficient decision making.

XI. Suggested Reading

- EO Heady. *Economics of Agricultural Production and resources use*.
- John P Doll and Frank Orazem. *Production Economics: Theory with application*
- Heady EO & Dillon JL. 1961. *Agricultural Production functions.* Kalyani Publishers, Ludhiana, India. 667 p.
- Baumol WG. 1973. *Economic theory and operations analysis*. Practice Hall of India Private Limited, New Dehli.626 p.

- Gardner BL & Rausser GC. 2001. *Handbook of Agricultural Economics* Vol. I Agricultural Production. Elsevier.

I. **Course Title : Agricultural Marketing and Price Analysis**

II. **Course Code : AEC 503**

III. **Credit Hours : 2+1**

IV. **Why this course?**

The ultimate aim of production process is to sell the produce in the market and generate income. Markets serves as platform where this exchange takes place.

Agriculture markets are different from other markets due to the nature of the commodity. Thus, it is important to develop a strong foundation of agricultural marketing, its components and issues. The student needs to know about the multi- pronged ways of marketing the produce, agencies involved. In this modern era, it is important to understand how technology is transforming this sector.

V. **Aim of the course**

The course is designed to acquaint the students about the basics of dynamics of agricultural marketing. The content includes supply, demand and marketing of farm production, marketing functions and channels, marketing costs, margins and efficiency, agricultural prices, New marketing formats like e-marketing, e-NAM future trading, supply chain management, market intelligence etc.

VI. **Organization of the course**

The course is organised as follows:

No	Block	Unit
1.	Introduction to Agricultural Marketing	1. Introduction to agricultural marketing
2.	Agricultural markets	1. Aspects of agricultural marketing 2. Future marketing and government
3.	Advances in agricultural marketing	1. Use of information technology 2. Dynamics of price

VII. **Theory**

Block 1: Introduction to Agricultural Marketing

Unit 1: Introduction to agricultural marketing

New Concepts in Agricultural Marketing - Characteristic of Agricultural product and Production – Problems in Agricultural Marketing from Demand and Supply and Institutions sides. Market intermediaries and their role - Need for regulation in the present context - Marketable & Marketed surplus estimation. Marketing Efficiency - Structure Conduct and Performance analysis - Vertical and Horizontal integration - Integration over space, time and form-Vertical co-ordination.

Block 2: Agricultural Markets

Unit 1: Aspects of agricultural marketing

Different Forms of marketing: Co-operatives Marketing – APMC Regulated Marketing - Direct marketing, Farmer Producer Companies, e-NAM and marketing under e-NAM, e-marketing Contract farming and Retailing, Organized retailing - Supply Chain Management - State trading, Warehousing and other Government agencies -Performance and Strategies -Market infrastructure needs, performance and Government role - Value Chain Finance.

Unit 2: Future marketing and government

Introduction to Commodities markets and future trading - Basics of commodity futures - Operation Mechanism of Commodity markets – Price discovery - Hedging and Basis - Fundamental analysis - Technical Analysis – Role of Government/SEBI in promoting commodity trading and regulatory measures.

Block 3: Advances in Agricultural Marketing

Unit 1: Use of Information Technology

Role of Information Technology and Market Intelligence in marketing of agricultural commodities, -electronic auctions (e-bay), e-Chaupals, Agmarknet and Domestic and Export market Intelligence Cell (DEMIC).

Unit 2: Dynamics of price

Price forecasting – time series analysis – time series models – spectral analysis. Price policy and economic development – non-price instruments.

VIII. Practical

- Supply and demand elasticities in relation to problems in agricultural marketing.
- Price spread and marketing efficiency analysis.
- Marketing structure analysis through concentration ratios.
- Performance analysis of Regulated market and marketing societies. Analysis on contract farming and supply chain management of different agricultural commodities, milk and poultry products.
- Supply Chain Analysis - quantitative estimation of supply chain efficiency.
- Market Intelligence – Characters, Accessibility, and Availability Price forecasting.
- Online searches for market information sources and interpretation of market intelligence reports – commodity outlook.
- Technical Analysis for important agricultural commodities.
- Fundamental Analysis for important agricultural commodities.
- Presentation of the survey results and wrap-up discussion.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on price volatility and control measures prevailing.
- Power point presentations by students on government schemes.
- Visit to eNAM mandies, Warehouses, etc.

X. Learning outcome

After the completion of this course the student will be able to–

- Understand the whereabouts of agricultural marketing.
- The different forms of marketing existing in this sector.
- Gain expertise in market intelligence and price forecasting.

XI. Suggested Reading

- Acharya SS & Agarawal NL. 2004. *Agricultural Marketing in India*. Oxford and IBH Publishing company Pvt. Ltd. New Delhi.
- Acharya SS & Agarawal NL. 1994. *Agricultural Prices-Analysis and Policy*. Oxford and IBH Publishing company Pvt. Ltd. New Delhi.
- Richard H Kohls and Joseph N. Uhl: *Marketing of Agricultural products* by Collier MacMillan International.

I. Course Title : Macro Economics and Policy

II. Course Code : AEC-504

III. Credit Hours : 2+0

IV. Why this course?

The economy of the nation is governed by certain rules, regulation and principles. The students has to gain knowledge of the mechanism through which the large economies are controlled and ensure that welfare prevails. They are entitled to know the transactions between different markets and policies framed to keep value of money under control.

V. Aim of the course

The course envisages the concepts and principles of macroeconomics from classical to Keynesian theories. The other component deals with the monetary system- money, credit and banking system, value of money and economic activities, national income accounting and approaches to estimate national income theory of income and employment determination and inflation.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Conceptualising Macro economics and Concepts	1. Introduction: Measurement
2.	Theories of macroeconomics	1. Classical Macroeconomics 2. Income and spending: Keynesian Framework
3	Money, Consumption and Inflation	1. Money, Interest and Income 2. Theories of Aggregate Consumption and Investment 3. Inflation and Unemployment

VII. Theory

Block 1: Conceptualising Macro Economics

Unit 1: Introduction: Measurement and Concepts

Basic concepts and scope of Macro-economics, National Income Accounting: Methods of measurement of key macro-economic aggregates, relationship of national income and other aggregates (with numerical exercises), real and nominal income

Block 2: Theories of macroeconomics Unit 1: Classical Macroeconomics

Say's Law, Quantity Theory of Money, aggregate labour supply and demand of labour, Classical theory of determining output, wages and prices.

Unit 2. Income And Spending: Keynesian Framework

Simple Keynesian model of income determination; Keynesian Multiplier-aggregate spending, taxation, transfer payments, foreign spending, balanced budget; budget surplus (with numerical exercises).

Block 3- Money, Consumption and Inflation Unit 1: Money, Interest and Income

Goods market equilibrium-IS curve; Demand for Money, the Liquidity Preference Theory – Liquidity Trap; asset market equilibrium- LM curve; simultaneous equilibrium in goods and asset market- effect of fiscal and monetary policy

Unit 2: Theories of Aggregarte Consumption and Investment

Absolute Income Hypothesis, Relative Income Hypothesis, Fisher's Inter-temporal Choice Model, Life-Cycle and Permanent Income Hypotheses; Profits and Accelerator Theory.

Unit 3: Inflation and Unemployment

Inflation: Nature, Effects and control; Types of inflation – demand pull, cost push- stagflation, core inflation, hyperinflation; Phillips curve.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on inflation.

IX. Learning outcome

After the completion of the course the student will be able to-Understand the concepts of national income, theories build up to understand macroeconomics. Understand better about the policies and government steps taken to control the economic transaction of the nation. Workout how the investment acts as a catalyst in national development.

X. Suggested Reading

- Stonier & Hegue. *A Text Book of Economic Theory*
- Samuelson PA. 1948. *Foundation of Economic Analysis*. Harvard University Press
- MC Vaish Allid. 1983. *Macro–Economics Theory*
- Gardner Ackley. 1961. *Macro–Economics Theory*: Macmillan, New York.
- TF Dernburg & DM Mcdougali-*Macro Economics*
- G. Sirkin – *Introduction to Macro–Economics Theory*
- RL Heibroker-*Understanding Macro–Economics*
- JK Mehta –*Macro Economics*
- Michael R Edgemand – *Macro-Economics: Theory & Policy*

- David' W Pearce –*The dictionary of modern Economics*

I. **Course Title : Econometrics**

II. **Course Code : AEC 505**

III. **Credit Hours : 2+1**

IV. **Why this course?**

Development of analytical skills is imperative to make students proficient in conducting quality research work. The knowledge of variables, their models, and problems encountered when dealing with variables will build up a compatibility with the analytical aspects.

V. **Aim of the course**

The course provides knowledge of the econometric methods like time series analysis, linear regression models and their application in economic analysis. The course provides an insight into the econometric problems in analyzing time series and cross section data.

The course is organised as follows:

No	Block	Unit
1.	Introduction to econometrics	1. Introduction
2.	Classical Regression	1. Classical Linear Regression 2. Breaking down of Classical assumptions
3.	Qualitative Variables	1. Qualitative variables and simultaneous equation models

VII. **Theory**

Block 1: Introduction to Econometrics Unit 1: Introduction

Relationship between economic theory, mathematical economics, models and econometrics, methodology of econometrics-regression analysis.

Block 2: Classical Regression

Unit 1: Classical Linear Regression

Basic two variable regression – assumptions estimation and interpretation approaches to estimation – OLS and their properties – extensions to multi-variable models-multiple regression estimation and interpretation.

Unit 2: Breaking down of Classical assumptions

Violation of assumptions – identification, consequences and remedies for Multicollinearity, heteroscedasticity, autocorrelation – data problems and remedial approaches – model misspecification.

Block 3: Qualitative Variables

Unit 1: Qualitative variables and simultaneous equation models

Use of dummy variables- Introduction to simultaneous equations- identification problem

VIII. **Practical**

- Single equation two variable model specification and estimation

- Hypothesis testing transformations of functional forms and OLS application
- Estimation of multiple regression model
- Testing and correcting specification errors
- Testing and managing Multicollinearity
- Estimation of regressions with dummy variables

IX. Teaching Methods/ Activities

- Lectures.
- Assignments (Group/individual).

X. Learning outcome

After the completion of the course, the student will be able to- Understand the variables and the properties of regression models. Identify the problems in variables and remove them before conducting the analysis and avoid biased results.

- Dorfman R. 1996. *Linear Programming and Economic Analysis*. McGraw Hill.
- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis, A. 1997. *Theory of Econometrics*. Barner & Noble.
- Maddala GS. 2002. *Econometrics*. Mc Graw-Hill.
- Pinndyck RS and Rubinfeld DL. 1990. *Econometric Models and Econometric Forecasts*. McGraw Hill.

I. Course Title : Agricultural Development and Policy Analysis

II. Course Code : AEC-506

III. Credit Hours : 2+0

IV. Why this course?

The ultimate aim of the economies is to attain a satisfactory level of development. Development ensures that there is not only increase in income but also the distribution is such that lesser inequalities exist. The students need to know what is development and its related concepts. All the policies framed are with one sole objective of increasing the welfare. Thus, once concept of development is build up, students can better understand policies and their genesis.

V. Aim of the course

Concept of economic development and policy, theories of development, performance of Indian agriculture. The process and implementation of policies over a period of time.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Basic concepts	1. Introduction
2.	Theoretical Concepts Development	1. Theories of Agricultural

3.	Performance and policies	1. Performance of Indian Agriculture 2. Agricultural Policy: Process and Implementation

VII. **Theory**

Block 1: Introduction

Unit 1: Introduction

Role of agriculture in economic/ rural development – Evolution of thinking on agriculture and development; Agricultural development – meaning, stages and determinants – Population and food supply – need for sound agricultural policies

Block 2: Theoretical Concepts

Unit 1: Theories of Agricultural Development

Resource exploitation model- Conservation model- Location (Urban impact) model- Diffusion model- High pay-off input model-Induced Innovation Model-Agricultural R&D and Linkages

Block 3: Performance and policies

Unit 1: Performance of Indian Agriculture

Agrarian structure and land relations; trends in performance and productivity; agrarian structure and technology; credit, commerce and technology; capital formation; subsidies; pricing and procurement; Post Green Revolution agriculture; Production and productivity crisis in agriculture; Regional differences; Food Security, PDS system and Malnutrition.

Unit 2: Agricultural Policy: Process and Implementation

Instruments of Agricultural Policy; Process of agricultural policy formulation,

implementation, Monitoring and Evaluation in India; Global experiences in

participatory approach to Agricultural policy process; critical review of various elements of Indian agricultural policy-resource policies – credit policies – input and product marketing policies – price policies; WTO – Agreement on Agriculture; Planning models. Planning for utilization of resources and Indian Five Year Plans.

VIII. **Teaching Methods/ Activities**

- Lectures.
- Assignments (Group/individual).
- Group Discussions on evolution of Indian Agriculture and Development indices.
- Power point presentation by students on policies and their relevance.

IX. **Learning outcome**

After the completion of the course the student will be able to-Understand the concept of development and its preference over growth. Visualize how the agriculture sector is performing in this aspect. Understand the motive behind the policies and their implementation.

X. **Suggested Reading**

- Albert O. Hirschman 1958. *Strategy of Economic Development.* New Man Yale University
- Simon Kuznets 1965. *Economic Growth and Structures.* Oxford New Delhi.
- Das Gupta AK. 1965. *Planning and Economic Growth.* George Allen and Unwin London
- Robert E. Baldwin 1966. *Economic Development and Growth.* John Willey, New York

I. **Course Title : Agricultural Finance and Project Management**

II. **Course Code : AEC 507**

III. **Credit Hours : 2+1**

IV. **Why this course?**

Money is the fuel of driving all the economic activities. India is a land of small and marginal farmers. The financial conditions of the farmers is not so strong that they can finance themselves. They require credit to meet the requirements of inputs. Thus, the student should know the sources, principles involved and types of credit available. The institutions involved and on what grounds the finance is given to the farmer. What are the risks involved and how to overcome them.

V. **Aim of the course**

This course is designed with an objective to deliver knowledge of the principles, procedures, problems and policies relating to financing agricultural firms. In addition to this the students are also given knowledge about the research developments in the subject. The approach is analytic.

The course is organised as follows:

No	Block	Unit
1	Introduction to Agricultural Finance	1. Basic Concepts: A review
2.	Credit and financial analysis	1. Credit and its aspects 2. Financial analysis
3	Project and risk management	1. Project Overview 2. Risk and its Management

VII. **Theory**

Block 1: Introduction to Agricultural Finance Unit 1: Basic concepts: A Review

Role and Importance of Agricultural Finance. Financial Institutions and credit flow to rural/priority sector. Agricultural lending – Direct and Indirect Financing - Financing through Co-operatives, NABARD and Commercial Banks and RRBs. District Credit Plan and lending to agriculture/priority sector. Micro-Financing and Role of MFI's - NGO's, and SHG's.

Block 2: Credit and Financial Analysis

Unit 1: Credit and its aspects

Lending to farmers – The concept of 3 C's, 7 P's and 3 R's of credit. Estimation of Technical feasibility, Economic viability and repaying capacity of borrowers and appraisal of credit proposals. Understanding lenders and developing better working relationship and supervisory credit system. Credit inclusions – credit widening and credit deepening.

Unit 2: Financial analysis

Financial Decisions – Investment, Financing, Liquidity and Solvency. Preparation of financial statements - Balance Sheet, Cash Flow Statement and Profit and Loss Account. Ratio Analysis and Assessing the performance of farm/ firm.

Block 3- Project and Risk Management

Unit 1: Project Overview

Project Approach in financing agriculture. Financial, economic and environmental appraisal of investment projects. Identification, preparation, appraisal, financing and implementation of projects. Project Appraisal techniques – Undiscounted measures. Time value of money – Use of discounted measures - B-C ratio, NPV and IRR. Agreements, supervision, monitoring and evaluation phases in appraising agricultural investment projects. Net work Techniques – PERT and CPM.

Unit 2: Risk and its Management

Risks in financing agriculture. Risk management strategies and coping mechanism. Crop Insurance programmes – review of different crop insurance schemes - yield loss and weather based insurance and their applications.

VIII. Practical

- Development of Rural Institutional Lending;
- Branch expansion, demand and supply of institutional agricultural credit and Over dues and Loan waiving;
- An overview, Rural Lending Programmes of Commercial Banks, Lead Bank Scheme;
- Preparation of District Credit Plan, Rural Lending Programmes of Co-operative Lending Institutions;
- Preparation of financial statements using farm/firm level data, Farm credit appraisal techniques and farm financial analysis through financial statements;
- Performance of Micro Financing Institutions;
- NGO's and Self-Help Groups, Identification and formulation of investment projects;
- Project appraisal techniques – Undiscounted Measures and their limitations;
- Project appraisal techniques – Discounted Measures;
- Network techniques – PERT and CPM for project management;
- Case Study Analysis of an Agricultural project;
- Financial Risk and risk management strategies – crop insurance schemes;

- Financial instruments and methods – E banking, Kisan Cards and core banking.

IX. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions on inflation

X. Learning outcome

After the completion of the course the student will be able to- Understand the key issues of finance in Agriculture. Learn the techniques of assessing the worth of a project.

XI. Suggested Reading

- E Die Sollem H and Heady EO. (Ed.). *Capital and Credit Needs in Changing Agriculture,* Bauman.
- Hopkins A Barry, Peter Jo and Baker CB. *Financial Management in Agriculture*.
- Murray WG and Nelson AG. 1960. *Agricultural Finance*. Iowa State University
- Chanona C. 1969. *Agricultural Finance in India: Role of Commercial Banks*. Marketing and Economics Research Bureau, New Delhi.
- Gittinger JP. 1972. *Economic analysis of agricultural projects*, John Hopkins Univ. Press, Baltimore.
- Little IMD and JA Mirrless. 1974, *Project appraisal and planning for developing countries*,
  Oxford and IBH publishing Co. New Delhi.
- Arnold CH. 1972. *Project Evaluation, collected papers,* Macmillan.

I. Course Title : Linear Programming

II. Course Code : AEC-508

III. Credit Hours : 1+1

IV. Theory

Unit I

Decision Making- Concepts of decision making, introduction to quantitative tools, introduction to linear programming, uses of LP in different fields, graphic solutionto problems, formulation of problems.

Unit II

Simplex Method: Concept of simplex method-Solving profit maximization and cost minimizations problems. Formulation of farms and non farm problems as linear programming models and solutions.

Unit III

Extension of Linear Programming models: Variable resource and price programming, transportation problems, recursive programming, dynamic programming.

Unit IV

Game Theory- Concepts of game theory, two person constant sum, zero sum game, saddle point, solution to mixed strategies, the rectangular game as Linear

Programming.

V. Practical

- Graphical and algebraic formulation of linear programming models.
- Solving of maximization and minimization problems by simplex method.
- Formulation of the simplex matrices for typical farm situations.

I. Course Title : Research Methodology for Social Sciences

II. Course Code : AEC 509

III. Credit Hours : 1+1

IV. Why this course

Planning of research is very crucial to conduct a successful research. There is need to give an insight to the student about how to conduct a research, right from data collection to analysis and finally writing the references.

V. Aim of the course

The course deals with scientific methods of research, the initiation of an inquiry, formulation of research problems and hypotheses, the role of induction and deduction in research, collection and analysis of date and interpretation of results

VI. Organization of the course

The course is organized as follows:

No	Block	Unit
1.	Introduction to research methodology	1. Concepts of research methodology
2.	Building up hypothesis and sample selection	1. Hypothesis: Framing and Testing 2. Sampling
3	Data collection and analysis	1. Data collection 2. Data Analysis

VII. Theory

Block 1: Concepts of research methodology

Unit 1: Concepts of research methodology

Importance and scope of research in agricultural economics. Types of research –Fundamental vs. Applied. Concept of researchable problem – research prioritization – selection of research problem. Approach to research – research process.

Block 2- Building up hypothesis and sample selection

Unit 1: Hypothesis: Framing and Testing

Hypothesis – meaning – characteristics – types of hypothesis – review of literature setting of Course Objective and hypotheses – testing of hypothesis.

Unit 2: Sampling

Sampling theory and sampling design – sampling error - methods of sampling – probability and non-probability sampling methods - criteria to choose. Project proposals – contents and scope – different types of projects to meet different needs trade-off between scope and cost of the study. Research design and techniques Types of research design.

Block 3- Data Collection and Analysis

Unit 1: Data Collection

Data collection – assessment of data needs – sources of data collection – discussion of different situations. Mailed questionnaire and interview schedule – structured, unstructured, open ended and closed-ended questions. Scaling Techniques. Preparation of schedule – problems in measurement of variables in agriculture. Interviewing techniques and field problems - methods of conducting survey – Reconnaissance survey and Pre testing.

Unit 2: Data Analysis

Data coding, tabulation, cleaning. –Multivariate analysis –factor analysis' PCA' cluster analysis. Universal procedures for preparation of bibliography – writing of research articles.

VIII. Practical

- Exercises in problem identification.
- Project proposals – contents and scope.
- Formulation of Objective and hypotheses.
- Assessment of data needs – sources of data – methods of collection of data.
- Methods of sampling – criteria to choose – discussion on sampling under differentsituations.
- Scaling Techniques – measurement of scales.
- Preparation of interview schedule.
- Field testing. Method of conducting survey.
- Exercise on coding, editing, tabulation and validation of data.
- Preparing for data entry into computer.
- Hypothesis testing – Parametric and Non-Parametric Tests.
- Exercises on format for Thesis/ Report writing.
- Presentation of the results.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

After the successful completion of this course, student will be able to- Understand fundamentals of research. How to carefully plan out the research work and conduct it.

XI. Suggested Reading

- Baker CB. *Research Methodology in Agricultural Economics*
- Cohen MR and Nagel R. *An Introduction to Logic and Scientific Method*
- Devey J Logic. *The Theory of Enquiry*

- Dhondhyal SP. *Social Science Research and Thesis Writing*
- Ezekiel M. *Correlation Analysis*
- Heady EO. *Linear Programming Methods*
- Willson ER. *An Introduction to Scientific Research*
- Kumar A. 2008. *Research Methodology: A Survey.* Alts, New Delhi,

I. **Course Title : Indian Economy: History and Contemporary Issues Credit**

Course Code : AEC-510

Credit Hours : 2+0

Why this course?

India is a developing economy. The evolution of the Indian economy will enlighten the student with how an economy develops. Students will understand how the policies and measures taken shape up the economy of the country.

V. **Aim of the course**

To introduce the students to the economic history over a period of time. It also highlights the contemporary issues of Indian economy.

VI. **Organization of the course**

The course is organised as follows:

No	Block	Unit
1.	History of Indian Economy Liberalization	1. India from Independence to
		2. India since 1980's (Liberalization and Beyond): Overview
		3. Macro Trends Since 1990
2.	Contemporary Issues	1. Contemporary Issues

VII. **Theory**

Block 1- History of Indian Economy

Unit 1: India from Independence to Liberalization

An overview of the economic developments during the period 1947-1980; Objectives and strategies of planned economic development and the role of the State; Sectoral growth performance; savings and investment; Demographic trends and issues; education; health and malnutrition; Trends and policies in poverty; inequality and unemployment.Policy Changes since 1980s. The 1990 Crisis. Causes and Effects of liberalization. Regional differences: infrastructure, primary, secondary and tertiary sector.

Unit 3: Macro Trends Since 1990

Growth; Savings and Investment, Employment; productivity; diversification; Agro-based industries; competition policy; foreign investment, Regional differences.

Block 2- Contemporary Issues

Unit 1: Contemporary Issues

Monetary and Financial trends- areas of government spending in India, Capital expenditure, revenue expenditure, plan expenditure, non plan expenditure, Deficits (fiscal, primary, revenue), impact of fiscal deficit on economy, Capital receipts,
revenue receipts, tax and non tax revenue, direct and indirect taxes, need to
rationalize tax structure. Goods and Services Tax (GST). Union Budget, Zero base budgeting, Gender budgeting, Fiscal devolution and centre state financial relations in India, WPI, CPI implicit deflators. Foreign Trade policy.

VIII. Teaching Methods/ Activities

- Lectures
- Power point presentation by students on monetary and fiscal policy in past and present.
- Assignments (Group/individual).
- Group Discussions on Tax and its reforms.

IX. Learning outcome

After the completion of the course the student will be able to-Visualize how the Indian economy has evolved. Get acquainted with the basic steps involved in the working of the national economy.

X. Suggested Reading

- Dutt and Sundaram. *Indian Economy*

I. Course Title : International Economics

II. Course Code : AEC 511

III. Credit Hours : 2+1

IV. Why this course?

The era of Globalisation, liberalization and privatization has unified the whole world. There is trade across national boundaries and one economy has effect on the other. Getting familiar with national economy is not sufficient to understand the mechanism of trade and economic aspects. Thus, this course is designed to teach student about the trade as international level.

V. Aim of the course

The major objective of this course is to give an insight of the interactions between national economies. What are the theories governing the trade across national boundaries. The methods involved to regulate the international trade and institutions involved.

The course is organised as follows:

No	Block	Unit
1.	Introduction	1. Concepts of International Economics
2.	Models, Rate and terms of trade	1. Barriers to trade
		2. Models of trade
		3. Rates and Terms of trade
3	Institutions	1. Trades Institutions

VII. Theory

Block 1- Introduction

Unit 1: Concepts of International Economics

Scope and Significance of International Economics – The role of trade- General Equilibrium in a Closed Economy (Autarky Equilibrium) – Equilibrium in a Simple Open Economy - Possibility of World Trade - Trade gains and Trade Equilibrium.

Block 2- Models, Rate and Terms of Trade

Unit 1: Barriers to trade

Tariff, Producer Subsidy, Export Subsidy, Import Quota and Export Voluntary

Restraints- The Case of Small Country and Large Country Case.

Unit 2: Models of trade

Ricardian Model of Trade- Specific Factors Model- Heckscher - Ohlin Model - Trade Creation and Trade Diversion – Offer Curve - Export Supply Elasticity and Import Demand Elasticity – Comparative Advantage and Absolute Advantage.

Unit 3: Rates and Terms of trade

Official Exchange Rate and Shadow Exchange Rate - Walra's Law and Terms of Trade – Trade Blocks.

Block 3- Institutions

Unit 1: Trades Institutions

IMF, World Bank, IDA, IFC, ADB – International Trade agreements – UruguayRound – GATT – WTO.

VIII. Practical

- Producer's Surplus, Consumer's Surplus, National Welfare under Autarky andFree Trade Equilibrium with small and large country assumption.
- Estimation of Trade Gains
- Estimation of competitive and comparative measures like NPC, EPC, ERP andDRC
- Estimation of Offer Curve Elasticity
- Estimation of Effect of Tariff, Export Subsidy, Producer Subsidy, Import

Quota and Export Voluntary Restraints on National Welfare
- Estimation of Ricardian Model
- Estimation of Effect of Trade under Specific Factor Model
- Estimation of trade Equilibrium under Heckscher -Ohlin model

IX. Teaching Methods/ Activities
- Lectures.
- Case studies.
- Assignments (Group/individual).
- Power point presentation on International Trade in current scenario.

X. Learning outcome

After successful completion of the course the student will be able to – Understand how trade take place between nations. Be able to work out strategies to maintain a favourable trade balance. Understand how the institutions play role in regulating the cross country trade and deal with the issues.

XI. Suggested Reading
- Kindelberger and Joshi PK. 2016. *International Economics* AITBS Delhi-110051
- Brouwer F. *International Trade and Food Security*. LEI - Wageningen UR, The Netherlands.

I. Course Title : Institutional Economics

II. Course Code : AEC 512

III. Credit Hours : 1+0

IV. Why this course?

Institutions are involved in framing of economic development. The human behavior is governed by the institutions working in their environment. Thus, the student need to understand the institutions and their working.

V. Aim of the course

To develop critical and informed understanding about institutions, their role in the working of economy. Exposure of issues, policies & regulations and its application in agricultural system

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1	Introduction	1. Basics of Institutional Economics
2.	Approaches	1. Institutional changes & Resource allocation
		2. Group and collective Approach
3.	Law Protection and Institutions	1. Property rights
		2. Agrarian Institutions

VII. **Theory**

Block 1: Introduction

Unit 1: Basics of Institutional Economics

Old and New Institutional Economics – Institutional Economics vs Neo-classical Economics. Definition of institutions – Distinction between institutions and organizations – Institutional evolution.

Block 2: Approaches

Unit 1: Institutional changes & Resource allocation

Institutional change and economic performance - national and international economic institutions. Transaction cost economics – Transaction costs and the allocation of resources. Transaction costs and efficiency. Asymmetric information - Moral hazard and Principal-Agent problem.

Unit 2: Group and collective Approach

Free rider problem – path dependency – Interlinked transactions. Collective action and the elimination of free-rider problem - The logic of collective action and its role in reducing free rider problem – theory of Groups. Rent seeking – interest groups and policy formulation.

Block 3: Law Protection and Institutions

Unit 1: Property rights

Economic analysis of property rights- property rights regimes – private property – State Property - Common property Resources (CPRs) – public goods and club goods.

Unit 2: Agrarian Institutions

Special features of institutional arrangements in agriculture – Transaction costs in agriculture - Case Studies - Theories of agrarian institutions - tenancy institutions.

VIII. **Teaching Methods/ Activities**

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on Property rights

IX. **Learning outcome**

After successful completion of this course the student will be able to- Understand institutions and their roles in economic development. Know about the policies and their issues in an institutions.

X. **Suggested Reading**

- Pearce DW –*The dictionary of modern Economics*

I. **Course Title : Natural Resource and Environmental Economics**

II. **Course Code : AEC 513**

III. **Credit Hours : 1+1**

IV. **Why this course?**

Sustainable development is the need of the hour. The economic activities affect not only the society but also the environment. Every activity has its social cost. The students, hence will be taught about the economic aspect of environment.

V. Aim of the course

To understand about economics of environment and social costs incurred due to economic development. Work out methods to maintain environment quality and reduce social costs

The course is organised as follows:

No	Block	Unit
1.	Introduction to natural resource	1.Basic
2.	Insight of the subject resources	1. Theories and economics of natural
		2. Functioning of Market
		3. Sustainability aspects
3	Dealing with Issues and sustainability	Environmental Issues
		Regulations

VII. Theory

Block 1- Introduction to natural resource and environmental economics
Unit 1: Basic Foundation

Concepts, Classification and Problems of Natural Resource Economics – Economy Environment interaction – The Material Balance principle, Entropy law-Resources Scarcity - Limits to Growth - Measuring and mitigating natural resource scarcity
– Malthusian and Recardian scarcity – scarcity indices - Resource Scarcity and Technical Change.

Block 2- Insights of the subject

Unit 1: Theories and economics of natural resources

Theory of optimal extraction renewable resources –economic models of oil extraction- efficiency - time path of prices and extraction - Hotelling's rule, Solow-Harwick's Rule. Theory of optimal extraction exhaustible resources – economic models of forestry and fishery.

Unit 2: Functioning of Market Efficiency and markets – market failures - externalities – types - property rights – transaction costs – Coase's theorem and its critique - public goods - common property and open access resource management - Collective action.

Block 3- Dealing with the issues and sustainability

Unit 1: Environmental Issues

Environmental perspectives - biocentrism, sustainability, anthropocentrism - Environmental problems and quality of environment - Sources and types of pollution -air, water, solid waste, land degradation – environmental and economic impacts - Economics of pollution control - efficient reduction in environmental pollution.

Unit 2: Regulations

Environmental regulation – economic instruments - pollution charges – Pigovian tax - tradable permits – indirect instruments – environmental legislations in India.

Unit 3: Sustainability aspects

Concept of sustainable development – Economic Perspective – Indicators of sustainability Relation between development and environment stress- Environmental Kuznet's curve Environmental Accounting – resource accounting methods - International Environmental Issues – climate change – likely impacts – mitigation efforts and international treaties.

VIII. Practical

- Exhaustible resource management – optimum rate of oil extraction.
- Renewable resource management – optimum harvest of Forestry/fishery.
- Exercise on pollution abatement-I.
- Exercise on pollution abatement-II.
- Concepts in valuing the environment.
- Taxonomy of valuation techniques.
- Productivity change method – substitute cost method – Hedonic price method –Travel cost method – Contingent valuation methods.
- Discount rate in natural resource management.
- Environment impact assessment
- Visit to Pollution Control Board.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual)

X. Learning outcome

After successful completion of this course, the student will be able to-Work out the plan for extraction / use of natural resource in most economical way. Understand the environment and its pollution. Learn how markets are affected if environment is not taken into consideration. Gain proficiency in rules and regulation governing economic aspect of environment.

XI. Suggested Reading

- Pearce DW and Turner RK. *Economics of Natural Resource and Environment*
- Kwak J. *Economism: Bad Economics and the Rise of Inequality*
- Tietenberg T and Lewis L. *Environmental and Natural Resource Economics*
- Schwarz PM. *Energy Economics*

I. Course Title : Commodity Future Trading Credits

II. Course Code : AEC 514

III. Credit Hours : 2+0

IV. Why this course?

Risk is involved in marketing. Price fluctuation is a very common phenomenon in agriculture marketing. In such situation selling of commodity in future market serves as a resort to insulate from this uncertainty. Thus, knowledge of futures market is helpful in ...

V. **Aim of the course**

To disseminate the knowledge about risk mitigating measures especially future trading. The future trading in agricultural commodities is increasing day by day therefore the role of SEBI, functioning of commodity exchanges are discussed.

The course is organised as follows:

No	Block	Unit
1.	Introduction to commodity market future trading	1. Concepts of commodity
2.	Techniques and risks in commodity market	1. Technical aspects 2. Risk and its Management
3.	Commodity exchange and market	1. Commodity Exchange–A reviewanalysis 2. Analysis of commodity market

Theory

Block 1- Introduction to commodity market Unit 1: Concepts of commodity future trading

History and Evolution of commodity markets – Terms and concepts: spot, forward and futures Markets – factors influencing spot and future markets. Speculatory mechanism in commodity futures.

Block 2- Techniques and Risks in Commodity Market

Unit 1: Technical aspects

Transaction and settlement – delivery mechanism - role of different agents - trading strategies -potential impact of interest rate, Foreign Exchange, FDI in Commodity Markets.

Unit 2: Risk and its Management

Risk in commodity trading, importance and need for risk management measures

- managing market price risk: hedging, speculation, arbitrage, swaps - pricing and their features.

Block 3- Commodity exchange and market analysis

Unit 1: Commodity Exchange – A review

Important global and Indian commodity exchanges - contracts traded – special

features -Regulation of Indian commodity exchanges - FMC and its role.

Unit 2: Analysis of commodity market

Fundamental Vs Technical analysis – construction and interpretation of charts and chart patterns for analyzing the market trend – Market indicators – back testing. Introduction to technical analysis software – analyzing trading pattern of different commodity groups.

VII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions.
- Power point presentations by students.

VIII. Learning outcome

After successful completion of this course, the student will be able to-The basic concepts of commodity markets. The national and international commodity markets.

IX. Suggested Reading

- Kaufman PJ. *The Concise Handbook of Futures Markets*: Jhon Wiley & Sons
- Purcell WD. *Agricultural Futures and Options: Principles and Strategies*: MacMillan Publications
- Wasendorf RR & McCaffery *All About Commodities from the Inside Out.* McGraw Hill

I. Course Title : Development Economics

II. Course Code : AEC-515

III. Credit Hours : 2+0

IV. Why this course?

Development is more important than growth. The development of a nation ensures that condition of welfare prevails. The students has to understand different measures of development. How to measure them and relevant theories.

V. Aim of the course

To develop concept of growth and development. Methods and theories of measuring development. Study of different developed economies will give exposure towards measures to create economic upliftment.

VI. Learning outcome

After successful completion of this course, the student will be able to-Measure the development using different methods. Understand the theories of development and relate it to real world.

VII. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to Development Economics	1. Conceptions of Development
2.	Theories and comparison	1. Theories of Economic growth and development 2. Comparative Economic Development

VIII. **Theory**

Block 1- Introduction to Development Economics Unit 1: Conceptions of Development

Development Economics – Scope and Importance - Economic development and economic growth - divergence in concept and approach - Indicators and Measurement of Economic Development –GNP as a measure of economic growth – New Measures of Welfare – NEW and MEW – PQLI – HDI – Green GNP - Criteria for under development – Obstacles to economic development – Economic and Non-Economic factors of economic growth- Development issues, poverty, inequality, unemployment and environmental degradation.

Block 2- Theories and comparison

Unit 1: Theories of Economic growth and development

Classical theories- Adam smith - Ricardo- Malthus, Marx's theory of economic development; Schumpeter's theory, Approaches to development- low income equilibrium trap - critical minimum effort- The Strategy of economic development- Balanced vs. Unbalanced growth, choice of technique, investment criteria, big push theory, Rostow's stages of Economic Growth, unlimited supply of labour; social and technological dualisms; roles of capital accumulation, human capital and technological change in economic development, Models of economic growth Harrod- Domar, Kaldor, Mahalanobis, Lewis, FeiRanis, Input-Output, multisectoral models.

Unit 2: Comparative Economic Development

Countries selected for case studies -USA, Japan, China and India; Overview of economic development is selected countries; agrarian surplus and the role of the peasantry in economic development; industrial revolution; division of labour, organisation of work and industrial production, the role of the State in developmental transition

IX. **Teaching Methods/ Activities**

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on inflation

X. **Suggested Reading**

- Blaug M. 1986. *Economic History and the History of Economic Thought*
- Chenery HB and TN Srinivasan. *Handbook of Development Economics*
- Baldwin RE. *Economic Development and Growth*. John Willey, New York

I. **Course Title : Applied Sciences /Mathematics for Agricultural Economics**

II. **Course Code : STAT/AEC STAT 501**

III. **Credit Hours : 3+0**

IV. **Why this course?**

Knowledge of calculus is basic requirement for carrying out simple calculations.

V. Aim of the course

To solve various mathematical problems in economic research. Calculations are integral part of research analysis therefore it has wide application in economic studies.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction	1. Preliminaries
2.	Variables and functions	1. Variables and functions 2. Differentiation of functions
3.	Overview of linear algebra	1. Linear Algebra 2. Optimization of functions 3. Integration of functions

Block 1- Introduction

Unit 1: Preliminaries

Logic and proof techniques; sets and set operations; relations; functions and theirproperties; number systems

Block 2- Variables and functions

Unit 1: Variables and functions

Specific functions is economic theory. Elementary analytical geometry-gradient and equation of straight line. Standard equations and simple properties of circle, parabola and rectangular hyperbola.

Unit 2: Differentiation of functions

Limit and continuity. Differentiation, theorems of differentiation, differentiation of logarithmic and exponential functions, function of a function, derivative of higher order, partial derivatives. Application of derivatives to determine average and marginal values in economic analysis; determination of elasticities; points of inflexion; linear homogenous production functions; derivation of average and marginal curves.

Block 3- Overview of Linear Algebra

Unit 1: Linear Algebra

Determinants, evaluation and properties of determinants, Vectors and vector spaces, Matrices, notations and operations, laws of matrix algebra; transpose and inverse of matrix; Solution of linear and quadratic equations involving one variable, simultaneous equations, application of determinants and matrices in solution ofequation for economic analysis.

Unit 2: Optimization of functions

Optimization- unconstrained, maxima and minima, constrained optimization, Lagrange multiplier and their economic applications for optimization problems of cost, production, demand and supply.

Unit 3: Integration of functions

Integration as a reverse process of differentiation, methods of integration, reduction formulae, definite integral, use of integration to determine relation between average and marginal value. Capitalization over time, estimation of returns from capital goods over time. Pareto distribution.

VII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Power point presentations

VIII. Learning outcome

After successful completion of this course, the student will be able to- Develop eXpertise in calculus operations.

Course Title with Credit Load Ph.D. in Agricultural Economics

Major Courses: 12 credits

Course Code	Course Title	Credit Hours
AEC-601	Advanced Micro Economic Analysis	2 (1+1)
AEC-602	Advanced Macro Economic Analysis	2 (2+0)
AEC-603	Advanced Econometrics	3 (2+1)
AEC-604	Advanced Production Economics	3 (2+1)
Common	Research and Publication Ethics	2(2+0)

Minor Courses: 06 credits

a. It is suggested the student may choose at least one out of three courses listed below as part of minor courses as these are related to policy advocacy and bring in global perspectives with an aim to build a larger understanding of the subject to the student.

b. Further, it is suggested that the student may choose the remaining Courses from any other discipline including the disciplines of Agril. Economics/ ABM and are related to the research problem selected by the student.

c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/ HoD.

AEC-606	Advanced Agricultural Marketing and Price Analysis	3 (2+1)
AEC-607	Quantitative Development Policy Analysis	2 (1+1)
AEC-608	Natural Resource Management	3 (2+1)
AEC-609	Environmental Economics	3(2+1)

Minor courses may be taken from above list or subjects closely related to a student's major subject

Supporting Courses: 05 credits

AEC-605	Operations Research	3 (2+1)

One course of 600 series of 2 credits from Statistics or computer discipline may betaken depending upon availability.

- Some of these courses are available in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on SWAYAM or any other platform.
- If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the HoD/ BoS.
- It is also suggested that the student may choose the Supporting Courses other than the listed courses, provided the opted courses are related to the research problem selected by the student and be mandatorily approved by the Student Advisory committee/HoD".

AEC-660	Doctoral Seminar -I	1(1+0)
AEC-661	Doctoral Seminar -II	1(1+0)
	RESEARCH	75
	Total	100

There will be two Doctoral Seminar and a research scholar has to published one review paper as output of these seminar. At Ph.D. level, Research Plan Proposal (RPP)be delivered by the end of SEM II

Course Contents
Ph.D. in Agricultural Economics

I. **Course Title : Advanced Micro Economic Analysis**

II. **Course Code : AEC 601**

III. **Credit Hours : 1+1**

IV. **Why this course?**

This course is required to upscale the knowledge of students about micro economics. So that they can get a deeper and better understanding of the subject.

V. **Aim of the course**

To gain fundamental understanding of consumer behavior, producer's strategy, market structure through which transactions take place and human and firms interact. Develop foundation of scarce resource allocation for optimum results.

VI. **Organization of the course**

The course is organised as follows–

No	Block	Unit
1.	Consumer Theory	1. Consumer Theory
2.	Market and General quilibrium	1. Market 2. General Equilibrium
3.	Market failure and welfare	1. Market Failure 2. Welfare Economics

VII. **Theory**

Block 1- Consumer Theory

Unit 1: Consumer Theory

Theory of consumer behavior – Duality in consumer theory - expenditure function and indirect utility function - Measurement of Income Effect and Substitution Effect. Measurement of Changes in Consumers' Welfare – Consumer's Surplus, Compensating Variation and Equivalent Variation - Dynamic versions of demand functions – Integrability of demand functions. Demand Models – Linear Expenditure System, Almost Ideal Demand System. Applications of consumer theory – Household model and time allocation –

Labour supply decisions by households.

Block 2- Market and General Equilibrium

Unit 1: Market

Perfect competition – Monopoly, monopolistic competition and oligopoly. Oligopoly models – collusive and non-collusive models of oligopoly - Cournot model, Chamberlin model, Stackleberg solution.

Unit 2: General Equilibrium

General equilibrium theory – Conceptual overview - General equilibrium conditions with Production and Consumption. Existence, Uniqueness and Stability of general competitive equilibrium. Walrasian general equilibrium – Mathematical derivation of conditions for general equilibrium.

Block 3- Market Failure and Welfare

Unit 1: Market failure

Market failure - Incomplete markets - Asymmetric information – Principal-Agent problem, adverse selection and moral hazard. Externalities – Network externalities, Public goods – Optimal provision of public goods.

Unit 2: Welfare Economics

Welfare Economics - Concepts, problems, approaches and limitations of Welfare Economics, Pareto conditions of maximum welfare – Criteria for social welfare - Social Welfare functions, Social versus Private costs and benefits.

VIII. Practical

- Problems in consumer utility maximization
- Estimation of income and substitution effects;
- Estimation and comparison of Consumer's surplus, equivalent variation and compensating variation.
- Estimation of demand models – Derivation and estimation of labour supply equations from household models comparative static analysis in consumption.
- Advanced problem solving in price determination under perfect competition,monopoly, oligopoly and monopolistic competition.
- Game theory models.
- Problems solving in General Equilibrium Theory and Welfare Economics.
- Problems in public goods provision.

IX. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions

X. Learning outcome

After successful completion of the course, the student will be able to- Understand the different market competition. Work out strategies for attaining equilibrium in the market.

XI. Suggested Reading

- Henderson JM and Quandt RE. *Microeconomic Theory: A Mathematical Approach* Tata McGraw Hill Publishing Co Ltd
- Koutsoyiannis A. *Modern Micro Economics.* Macmillan Press Ltd
- Ferguson and Gould. *Micro Economic Theory.* Richard D Erwin Inc USA

I. **Course Title : Advanced Macro Economics**

II. **Course Code : AEC-602**

III. **Credit Hours : 2+0**

IV. **Why this course?**

A deeper understanding of the conceptual and structural framework is imperative to develop vision of a student about how the knowledge of various macroeconomic

V. **Aim of the course**

To understand the functioning of national economy, its history and models. The policies governing the modern economic system and concerned institutions.

VI. **Organization of the course**

The course is organised as follows–

No	Block	Unit
1.	Introduction	1. Overview
2.	Economic Models	1. Open Economy Models
		2. Dynamic Macroeconomic Models
3.	Business cycle and pollicies	1. Business Cycles
		2. Macroeconomic Polices

VII. **Theory**

Block 1- Introduction

Unit 1: Overview

Conceptual framework - Classical, Keynesian, Neo-Classical, and Neo-Keynesian macroeconomics; Review of Keynes-Classical Synthesis; Aggregate Demand and Supply in the closed economy with fixed and variable price level- determination of wage, prices, output and employment

Block 2- Economic Models

Unit 1: Open Economy Models

Exchange rate determination; purchasing power parity; asset market approach; Short-run open economy models; Mundell-Fleming model- exchange rate regime: perfect capital mobility under fixed and flexible exchange rate; effectiveness of fiscal policy and monetary policy; Dornbusch's overshooting model; monetary approach to balance of payments;

international financial markets

Unit 2: Dynamic Macroeconomic Models

Introduction to dynamic macroeconomic Models; Dynamic aggregate demand andsupply – short and long term equilibrium- rational expectations approach

Block 3: Business Cycle and Policies

Unit 1: Business Cycles

Business cycle and its alternative equilibrium model, Stability analysis Economics of Great Events-Depression, Hyperinflation and Deficits; Advances in Business Cycle Theory; Real Business Cycles & Neo-Keynesian Economics

Unit 2: Macroeconomic Polices

Monetary policy - Design of Monetary Policy; Inflation Targeting, Fiscal Policy - Government Budget Constraint: The Arithmetic of Deficits and Debt, Current versus Future Taxes, the Evolution of Debt-to-GDP Ratio; Public Borrowing-Internal and external aid, Deficit financing, Development Financing; BOP & Adjustment Policies - Foreign Exchange Policy - International macro-economic policies, IMF, IBRD, UNCTAD.

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

IX. Learning outcome

After successful completion of this course the student will be able to- Figure out how policies are framed to safe guard the national economy. Understand the rationale behind the working of different economy.

X. Suggested Reading

- Heibroker RL. *Understanding Macro Economics.*
- Mehta JK. *Macro Economics.*
- Edgemand MR. *Macro-Economics: Theory & Policy.*
- David' W Pearce. *The dictionary of modern Economics.*
- Allen RGD. 1968. *Macro–Economic Theory: A Mathematical Treatment.* London: Macmillan.
- Stanlake GF. *Macro–Economics: An Introduction*. Longman, London.
- Mithai DM. 1981. *Macro–Economics: Analysis and Policy*. Oxford and IBH, New Delhi.
- Hicks JR *Critical Essays in Monetary Theory.*
- Nawiyn WT. *Theory of Money*.

I. Course Title : Advanced Econometrics

II. Course Code : AEC 603

III. Credit Hours : 2+1

IV. Why this course?

The heart of any research is carrying out the analysis with the most appropriate model. The results obtained are crucial for the researchers. Thus, this course actsas the centre point of building up analytical framework of research. The students need to learn building up of models that will be used to test the hypothesis framed. Use different analysis depending upon the requirement and type of data.

V. Aim of the course

The course aims at providing the knowledge and command over analysis of data collected to get the desired result. Train the student in use of econometric models.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Concepts	1. Review
2.	Least squares and dummy variables	1. Concept of Least Squares 2. Dummy Variable
3.	Econometric models	1. Models and their extensions 2. . Simultaneous equation modles

VII. Theory

Block 1: Concepts

Unit 1: Review

Review of classical regression model – review of hypothesis testing – restrictions

Block 2: Least Squares and Dummy Variables

Unit 1: Concept of least squares

Ordinary least squares – weighted least squares - generalized least squares –

method of principal components – instrumental variables method - maximum

likelihood method - errors in variables, non-linearity and specification tests – nonspherical error terms.

Unit 2: Dummy Variable

Dummy variables - Qualitative and truncated dependent variables - limited dependent variables –LPM, probit and logit models, their multinomial extensions.

Block 3: Econometric Models

Unit 1: Models and their extensions

Autoregressive distributed lag models – panel data fixed and random effects models and their extensions.

Unit 2: Simultaneous equation models

Simultaneous equation methods –identification – estimation by indirect least squares 2SLS, PIML, SURE, 3SLS

VIII. Practical

Estimation of multiple regression model - GLS estimation methods - testing misspecification errors – Testing and Managing multicollinearity, heteroscedasticity and autocorrelation - estimation of LPM, Logit and Probit models - comparing two regressions - Chow test - estimation of distributed lag models – panel data random and fixed effects models - Indirect least squares 2SLS, SURE, 3SLS, estimation of simultaneous equation models.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/ individual).
- Group Discussions

X. Learning outcome

After successful completion of the course, the student will be able to–

- Analyse the data collected for testing the framed hypothesis.
- Get expertise in analytical framework.

XI. Suggested Reading

- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis A. 1997. *Theory of Econometrics*. Barner & Noble.

I. Course Title : Advanced Production Economics

II. Course Code : AEC 604

III. Credit Hours : 2+1

IV. Why this course?

There is requirement of getting acquainted with decision making process in case of factors and products. The researcher needs to understand about working on production process and work out suitable suggestions to improve it.

V. Aim of the course

The course deals with the concept of advanced production economics. The exposition would be mathematically oriented. The course would also cover the analysis of production functions, its interpretation, decision making with multiple input use, factor sharing and decision making under risk and uncertainty..

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Consumer Theory	**1.** Production Process
2.	Market and General quilibrium	1. Production Functions and characteristics
3.	Market failure and welfare	1. Decision Making in Production

2. Technology, Efficiency and Risk Management
3. Programming

VII. Theory

Block 1: Production process Unit 1: Production Process

Agricultural Production process – Relationship between farm planning and production economics-scope of agricultural production and planning-methods/ procedures in agro-economic research and planning.

Block 2: Production Function

Unit 1: Production Functions and characteristics

Production functions, components, assumptions, properties and their economic interpretation - Concepts of homogeneity, homotheticity,, APP, MPP, elasticities of substitution and their economic relevance – Production relations – optimality-Commonly used functional forms, nature, properties, limitations, estimation and interpretation - linear, Spillman - Cobb Douglas, quadratic, multiplicative (power) functional forms - Translog, and transcendental functional forms - CES, production functional forms-Conceptual and empirical issues in specification, estimation and application of production functions- Analytical approaches to economic optimum - Economic optimum – determination of economic optimum with constant and varying input and output prices - Economic optimum with production function analysis - input use behaviour.

Block 3: Dynamics of production process

Unit 1: Decision Making in Production

Decision making with multiple inputs and outputs – MRT and product relationship- cost of production and adjustment in output prices-single input and multiple product decisions- Multi input, and multi product production decisions - Decision making with no risk -Cost of wrong decisions - Cost curves – Principles and importance of duality theory - Correspondence of production, cost, and profit functions - Principles and derivation of demand and supply functions

Unit 2. Technology Efficiency and risk Management

Technology, input use and factor shares -effect of technology on input use-decomposition analysis-factor shares-estimation methods- Economic efficiency in agricultural production – technical, allocative and economic efficiency – measurement -Yield gaps analysis – concepts and measurement - Risk and uncertainty in agriculture – incorporation of risk and uncertainty in decision making – risk and uncertainty and input use level-risk programming.

Unit 3: Programming

Simulation and programming techniques in agricultural production-Multiple Objective Programming (MOP) – Goal programming, Weighted sum and Compromise programming – applications.

VIII. Practical

Estimation of different forms of production functions- Optimal input and product choice from estimated functions-Derivation of demand and supply functions and estimation-Estimation of cost function and interpretations-Optimal product and input choice under multi input and output system-Estimation of factor shares from empirical functions estimated-Estimating production functions incorporating technology changes: Decomposition analysis and incorporation of technology- Estimation of efficiency measures – Stochastic, probabilistic and deterministic frontier production functions-Risk programming – MOTAD-Quadratic programming- Simulation models for agricultural production decisions-Goal programming – Weighted, lexicographic and fuzzy goal programming-Compromise programming.

IX. **Teaching Methods/ Activities**

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. **Learning outcome**

After successful complétion of the course, the student will be able to-Get familiar with different production function and use them in practise and come out with useful decision. Work out the efficiency of the production process and use models for finding the optimum solution.

XI. **Suggested Reading**

- Baumol WG. 1973. *Economic theory and operations analysis*. Practice Hall of India Private Limited, New Dehli. 626 p.
- Gardner BL and Rausser GC. 2001. *Handbook of Agricultural Economics* Vol. I Agricultural Production. Elsevier.
- Heady EO. 1952. *Economics of Agricultural Production and resources use*. Practice Hall of India.
- Heady EO and Dillon JL. 1961. *Agricultural Production functions*. Kalyani Publishers, Ludhiana, India. 667 p.

I. **Course Title : Operations Research**

II. **Course Code : AEC-605**

III. **Credit Hours : 2+1**

IV. **Why this course?**

In sphere of management it is important, to take correct decision of assigning tasks and roles to individuals. The business is full of uncertainity and in this situation the manager has to take decision. It becomes imperative to gain knowledge of models used for finding this solution of performing well.

V. **Aim of the course**

To gain elementary knowledge of solving problems and decision making for managing farming and organisation in resource constraint in order to achieve the objective.

VI. **Organization of the course**

The course is organised as follows–

No	Block	Unit
1	Concepts	1. Concepts
2	Inventory and models	1. Inventory- A Review 2. Models
3	Decision making	1. Decision making 2. Game theory

VII. Theory

Block 1: Concepts

Unit 1: Concepts

Elementary concepts and objectives of Operations Research, Review of Linear programming - Assumptions & Methods, Non-linear programming problem - Quadratic programming, Multi Objective Programming (MOP)

Block 2: Inventory and Models

Unit 1: Inventory- A Review

Inventory control models, costs involved in Inventory management, types of inventory, Economic order quantity model, Waiting line models: Waiting line problem, Characteristics of a waiting line system, Single channel model,

Unit 2: Modles

Markov Chains, Sequencing, Replacement models, Transportation and Assignment problems.

Block 3: Decision Making

Unit 1: Decision Making

Decision making under risk and uncertainties, decision problem, maximax criterion, maximin criterion, minimax regret criterion, Laplace criterion, Pay off tables, Decision trees, Expected value of perfect information.

Unit 2: Game Theory

Game Theory – Two-person Zero sum game, Simulation, Network Analysis- PERT& CPM.

VIII. Practical

- Linear and Non-linear programming problem,
- Quadratic programming, Multi-Objective Programming- Goal Programming,
- Lexicographic, Weighted Sum, Determining economic order quantity, reorder levels of EOQ model.
- Waiting line problem, Problems on Markov Chains, Sequencing and Replacement models.
- Formulating and solving transportation type problems, Assignment problems as a special type of transportation problem.
- Solving deterministic and probabilistic queuing models Structuring and solving decision trees for optimal decisions Game theory,

Simulation, Developing network (PERT/CPM) diagrams and determining the critical path.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After successful completion of this course, the student will be able to-
Gain expertise in formulating problems of management into mathematical form and work out the optimum solutions.
Apply the knowledge of different models in better decision making and controlling of the firm.

XI. Suggested Reading

- Taha HA. *Operations Research: An Introduction*.
- Veerabhadrappa H. *An Introduction to Operations Research*.
- Gupta PK and Hira DS. *Operations Research*.
- Sharma R. *Operations Research*.
- Sharma JK. *Operation Research.*
- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis A. 1997. *Theory of Econometrics*. Barner & Noble.

I. Course Title : Advanced Agricultural Marketing And Price Analysis

II. Course Code : AEC 606

III. Credit Hours : 2+1

IV. Why this course?

Efficient markets, connectivity in markets, facilities of transport and storage ensure that there is growth in marketing of the produce as well as the industries based on those produce. The decision of selling the produce at the right time, and at a higher price is crucial to ensure remunerative returns to the farmer. Thus, this course is required to enhance the knowledge to students in agricultural markets and price analysis.

V. Aim of the course

To impact adequate knowledge and analytical skills in the field of agricultural marketing and enhance expertise in improving the performance of the marketing institutions and the players in marketing of agricultural commodities. Learning outcome: After successful completion of this course, the student will be able to- Gain the knowledge of marketing and agricultural prices. Work out the interaction between different markets and analyse their working. Gain expertise in forecasting of price and build up market intelligence.

The course is organised as follows:

No	Block	Unit

1.	Concepts	1. Agricultural Marketing- Insights
2.	Marketing Institutions and Dynamics	1. Institutions and their functions
		2. Market Dynamics
3.	Techniques	1. Commodity marketing
		2. Models for Analysis

VII. Theory

Block 1: Concepts

Unit 1: Agricultural Marketing-

Insights Importance of market analysis in the agricultural system - types of marketing-advantages and disadvantages - quantitative estimation -the distinguishing characteristics and role of agricultural prices -data sources for agricultural products and prices - softwares used in market analysis.

Block 2: Marketing Institutions and Dynamics

Unit 1: Institutions and their functions

Role of various formal institutions in agricultural marketing - and functions - measuring their efficiency - public - private partnership - institutional arrangements. Successful case studies.

Unit 2: Market Dynamics

Multi market estimation, supply response models. Market integration and price transmission - supply / value chain management. GAP analysis. Current trends in information in the changing agrifood system.

Block 3: Techniques

Unit 1: Commodity Marketing

Agricultural commodity marketing -spot and futures- marketing of derivatives- speculation, hedging, swap, arbitrage etc. commodity exchanges - price discovery and risk management in commodity markets-Regulatory mechanism of futures trading.

Unit 2: Models for Analysis

Lag operators and difference equations; stationary and stochastic processes; Unit roots and cointegration; conditional heteroscedasticity: ARCH and GARCH models

-forecast evaluation; methods of forecasting. price indices and econometric estimation and simulation.

VIII. Practical

- Estimation of demand/ supply forecasting,
- Supply chain/ value chain analysis for different commodities
- Commodity models- multi market estimation- time series analysis
- Market integration studies- price discovery price volatility estimation
- Commodity price forecasting using econometric softwares.
- Lectures.

- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Suggested Reading

- Acharya SS and Agarawal NL. 1994. *Agricultural Prices-Analysis and Policy*. Oxford and IBH Publishing company Pvt. Ltd, New Delhi.
- Acharya SS and Agarawal NL. 2004. *Agricultural Marketing in India.* Oxford and IBH Publishing company Pvt. Ltd, New Delhi.
- Kohls RH and Joseph N. Uhl: *Marketing of Agricultural products* by Collier MacMillan International.
- Rhodes VJ. 1978. *The Agricultural Marketing System*. Grid Pub. Ohio.

I. Course Title : Quantitative Development Policy Analysis

II. Course Code : AEC 607

III. Credit Hours : 1+1

IV. Why this course?

Policy reforms are inevitable. They are continuously required to deal with the loop holes of previous policy and control the present situation in a better manner. Reforms take place in both microeconomic and macroeconomic polies. The analysis of these policies help us to develop a framework for designing and implementing the policies.

V. Aim of the course

To develop expertise in understanding the rationale behind development of policies. Conceptualization of equilibrium and working out the economic implications of development policy. Learning outcome: After the completion of the course, the student will be able to-Conceptualize policy framework. Get acquainted with analysisng the policy and work out corrective solutions.

VI. Organization of the course

The course is organised as follows

No	Block	Unit
1.	Concepts	1. Policy Framework
2.	Demand-supply and household Analysis behaviour	1. Demand- Supply 2. Household Behaviour and models
3.	Approaches to review policy and approach to policy review welfare and programming	1. Multi-Pronged 2. General equilibrium

Theory

Block 1: Concepts

Unit 1: Policy Framework

olicy framework – goals, value, beliefs and welfare maximization. Market – Policy and State – State vs. Market – Failure of Policy –

Failure of Markets - Rationale for Government Intervention. Role of Quantitative Policy Analysis.

Block 2: Demand-supply and household behaviour Unit 1: Demand- Supply Analysis

Demand analysis for policymaking – Alternative approaches to demand analysis – Policy implications. Supply response – Alternative approaches to measurement of supply response – Nerlovian models of supply response – Policy implications.

Unit 2: Household Behaviour and models

Household behaviour and policy analysis – Household models.

Block 3: Approaches to review policy and welfare

Unit 1: Multi-Pronged approach to policy review

Partial equilibrium analysis – Concept of reference prices – Price distortions – indicators and impact. Transaction costs – Implications for efficiency and productivity
– Institutional solutions - Multi market approach to policy analysis.

Unit 2: General equilibrium and programming

Social Accounting Matrices and multipliers -– Computable General Equilibrium models to assess economy wide impact of policy changes. fuzzy goal programming- Compromise programming.

VII. Practical

- Review of criteria for policy evaluation
- Estimation of price elasticities
- Review of estimation of complete demand systems
- Estimation of Nerlovian supply Response model
- Review of Household models
- Specification and estimation of household models
- Partial equilibrium analysis
- Input–output table
- Social Accounting Matrix
- Construction of a SAM
- Computation of Multipliers
- Multi Market Analysis
- Review of Computable General Equilibrium Models.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

I. Course Title : Natural Resource Management
II. Course Code : AEC 608
III. Credit Hours : 1+1

IV. Why this course?

The environment envisages the whole living creatures' within it. There are resources we obtain from the nature and at the same time spoil the environment by exploiting the resources. Thus, it is necessary for the student to develop environment friendly plans to utilize the scarce resources.

Concept building on natural resources. Gaining expertise in economic aspect of natural resources and maintain a balance between economic gains and environment conservation. Learning outcome-After the completion of the course, the student will be able to-Understand the natural resources and methodolies to develop plans for their optimal use. Work out the economics of forest, fisheries and ground water. Be able to deal with the legal matters of the natural resourses.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Concepts	1. Concepts
2.	Models and Management resources	1. Models for economic view of natural 2. Management of water resources
3.	Regulations and planning	1. Property Rights 2. Dynamics of resource economics

VII. Theory

Block 1: Concepts

Unit 1: Concepts

Natural resources - definition - characteristics and classification. Stock dynamics of renewable and non-renewable resources. Equation of motion for renewable and non-renewable resources. Fundamental equation of renewable resources.

Block 2: Models and Management

Unit 1: Models for economic view of natural resources

Growth curves of fishery and forest resources. The role of time preference in natural resource use. Simple two-period model of optimal use of renewable and non-renewable resources. Advanced models of optimal resource use – Static Vs. dynamic efficiency in natural resource use Applications of dynamic programming and optimal control.

Unit 2: Management of water resources

Economics of groundwater use - optimal extraction of groundwater. Analytical and numerical solutions for optimal inter-temporal allocation of natural resources. Optimal harvesting of single rotation and multiple rotation forests. Optimal management of fishery.

Block 3: Regulations and planning

Unit 1: Property Rights

Property rights in natural resources and their implication for conservation and management of natural resources. Management of common property natural resources – Institutional arrangements for conservation and management of common pool fishery, groundwater and forestry resource.

Unit 2: Dynamics of resource economics

Resource scarcity – Natural resource degradation – Poverty and resource degradation

– Natural resource accounting - Pricing and valuation of natural resources – Natural resources policy. Practical Derivation of the fundamental equation of renewable resources-Estimation of growth curves and stock dynamics for fishery and forestry resources. Simple two period problem of optimal resource use – Numerical solution for simple two-period model of dynamic efficiency in natural resource extraction. Multi-period dynamic efficiency – Using Excel Solver in solving dynamic natural resource harvesting problems. Using analytical solution procedures for solving natural resource management problems – Optimal control.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

IX. Suggested Reading

- Hackett SC. 2001. *Environmental and Natural Resource Economics: Theory, Policy and the Sustainable Society*. M.E. Sharpe, Armonk, NY.
- Hartwick JM and Olewiler ND. 1998. *The Economics of Natural Resource Use*. 2nd Ed. Addison-Wesley Educational Publ.
- Kerr JM, Marothia DK, Katar Singh, Ramasamy C and Bentley WR. 1997. *Natural Resource Economics: Theory and Applications in India*. Oxford & IBH.
- Pearce DW and Turner K. 1990. *Economics of Natural Resources and the Environment*. John Hopkins Univ. Press.
- Prato T. 1998. *Natural Resource and Environmental Economics*. Iowa State Univ. Press.
- Sengupta R. 2000. *Ecology and Economy, an Indian Perspective*. Oxford Univ. Press.
- Tietenberg T. 2003. *Environment and Natural Resource Economics*. 6th Ed. Addison Wesley.

I. Course Title : Environmental Economics

II. Course Code : AEC 609

III. Credit Hours : 2+1

IV. Why this course?

Economics not only deals with transaction taking place between human beings within and across national boundaries. Each economic activity has a price to pay to the environment. The activity causes loss to the environment in various ways. Thus, as a student of economics it is necessary to work out the costs and returns in terms of losses to environment while carrying out these development/production activities.

V. Aim of the course

To understand the economic outcomes of environmental degradation. Make students proficient in decision making regarding environment protection, resource use, and conservation policy.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Overview Economics	1. Overview of Environmental
2.	Assessment and Development assessment Dynamics Aspects	1. Economic 2. Developmental
3.	Regulations and Issues	1. Accounting, Policies and Regulations 2. Environmental Issues

VII. Theory

Block 1: Overview

Unit 1: Overview of Environmental Economics

Environmental pollution as a consequence of market failure - Causes and consequences of market failure - Externalities - Public goods and externalities -Economics of pollution – Private vs. Social cost of environmental pollution – Property rights, environment and development – Theory of environmental policy.

Block 2: Assessment and Development Dynamics

Unit 1: Economic assessment

Environmental cost benefit analysis - Environmental impact assessment techniques Non-market valuation of environmental resources (WTP / WTA) - Environment, market and social welfare.

Unit 2: Developmental aspects

Economic growth and environmental cost - Growth oriented economic policies and their environmental impacts - Population and environmental quality - poverty and environmental degradation – Sustainable development – Indicators of sustainable development – Issues in sustainable development.

Block 3: Regulations and Issues

Unit 1: Accounting, Policies and Regulation

Environment, ecology and environmental accounting - Environmental pollution with respect to water and air - Land and forest resources related environmental pollution - Coastal externalities - Urbanization and environment - Basic approaches to environmental policy (Tax, subsidy, pollution permits, *etc*.) Green taxes - Political economy of environmental regulation and management.

Unit 2: Environmental Issues

Transboundary environmental problems - Economics of global warming, climate change and emission trading - Environment, international trade and development.

VIII. Practical

- Contemporary global environmental global environmental issues, movement, policies, programmes, laws and other regulatory mechanisms
- Criteria for evaluating the environment related projects and review of Environmental Impact Assessment (EIA) techniques
- Recreation demand models of environmental valuation
- Contingent valuation techniques
- Environmental Resource Accounting Techniques
- Discussion on the techniques dealing with air pollution and review of case studies on air pollution and its impacts - forest environment and wild life conservation
- Green GDP and Green house insurance
- Practical considerations and comparison of instruments of environmental policy
- Non-point source pollution control methodologies
- Environment in macroeconomic modeling
- Meta-analysis, economic valuation and environmental economics
- Multi-criteria methods for quantitative, qualitative and fuzzy evaluation problems related to environment
- Input output analysis, technology and the environment
- Computable general equilibrium models for environmental economics and policy analysis.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After the successful completion of the course, the student will be able to- Understand the concept of pollution and externalities caused by economic activity. Work out the economics of productions activities in terms of losses to environment. Learn about accounting of environmental costs and other issues related.

XI. Suggested Reading

- Hackett SC. 2001. *Environmental and Natural Resource Economics: Theory, Policy and the Sustainable Society*. ME. Sharpe, Armonk, NY.
- Hartwick JM and Olewiler ND. 1998. The Economics of Natural Resource Use. 2nd Ed. Addison-Wesley Educational Publ.
- Kerr JM, Marothia DK, Katar Singh, Ramasamy C and Bentley WR. 1997. *Natural Resource Economics: Theory and Applications in India.* Oxford & IBH.
- Pearce DW and Turner K. 1990. *Economics of Natural Resources and the Environment.* John Hopkins Univ. Press.
- Prato T. 1998. *Natural Resource and Environmental Economics.* Iowa State University Press.
- Sengupta R. 2000. *Ecology and Economy, an Indian Perspective*. Oxford University Press.
- Tietenberg T. 2003. *Environment and Natural Resource Economics*. 6th Ed. Addison Wesley.

COMMUNITY SCIENCE
FOOD AND NUTRITION

Course Title with Credit Load for M.Sc. in Community Science – Food & Nutrition

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
FN 501*	Macro and Micro Nutrients in Human Nutrition	3(3+0)
FN 502*	Public Health and Nutrition	3(2+1)
FN 503*	Techniques in Food Analysis	3(1+2)
FN 504*	Diet Therapy	3(2+1)
FN 505	Nutrition and Physical Fitness	3(2+1)
FN 506	Developments in Nutrition and Immunity	2(2+0)
FN 507	Clinical Nutrition	3(2+1)
FN 508	Nutrition Counselling	2(0+2)
FN 509	Food Safety and Standards	3(2+1)
FN 510	Nutritional Challenges in Life Cycle	3(2+0)
FN 511	Food Science	3(2+1)
FN 512	Food Processing Technology	3(2+1)
FN 513	Human Physiology	3(3+0)
FN 514	Institutional Food Service Management	2(1+1)
	Minor Courses (08 Credits)	
FN 515	Food Science and Technology	3(2+1)
FN 516	Food Biochemistry	3(2+1)
FN 517	Nutritional Biochemistry	3(2+1)
FN 518	Food Microbiology	3(2+1)
EECM 504	Technology Transfer and Management	3(1+2)
EECM 505	Dynamic Communication Skills	3(1+2)
	Supporting Courses (06 Credits)	
	Common Courses (05 Credits)	
FN 591	Seminar	1(0+1)
FN 599	Thesis/Research	30
	T O T A L	**70**

*Core Courses/Compulsory Courses

Course Code : **FN 501**
Course Title : **Macro and Micro Nutrients in Human Nutrition**
Credit Hours : **3(3+0)**

Rationale

Proper nutrition is the crux of human health along with safe water, sanitation, immunization, etc. Adequate knowledge about this core course on macro and micronutrients in totality will enable the students to handle the nutrition situations of a population and how to imply the knowledge for sustainable handling to induce better health and productivity. Therefore, the necessity lies in this core course.

Aim of the course

- To provide in-depth understanding related to macro and micro nutrients
- To impart knowledge about specific requirements of these nutrients as per age, sex, physiological condition, functions, metabolism sources, deficiency parameters for meaningful handling of normal and problem stricken situations.

Theory

Unit I: Carbohydrates

Body composition; Functions, sources, requirements, digestion and absorption of carbohydrates. Composition, classification and functions of dietary fibre; Role of dietary fibre, resistant starch and fructo-oligosaccharides in various physiological disorders; Glycemic response to carbohydrates.

Unit II: Proteins

Classification, functions, sources, digestion and absorption of proteins; Synthesis of non-essential amino acids in the body; Urea cycle; Protein quality; Relationship between energy and protein requirements; Regulation of food intake; Nutrient adaptation to low intake of energy and protein.

Unit III: Fats

Classification, functions, sources, digestion, absorption and deficiency disorders of lipids and essential fatty acids; Role of omega-3 and omega 6 fatty acids in physiological disorders.

Unit IV: Vitamins, minerals and water

Functions, absorption, requirement, sources, deficiency and toxicity of fat-soluble vitamins - A, D, E and K and water-soluble vitamins- thiamine, riboflavin, niacin, pyridoxine, folate, B_{12}, ascorbic acid, pantothenic acid, biotin and amygdalin; Functions, absorption, requirement, sources, deficiency and toxicity of macro minerals – calcium and phosphorus and micro minerals – iron, zinc, sodium, copper, cobalt, selenium and chromium; Water and electrolyte balance, functions and distribution of water in body, Electrolyte composition of body fluids and electrolyte balance.

Teaching Methods/ Activities

- Lectures
- Assignment (Reading/Writing)
- Group discussion
- Student presentation

Learning Outcome

Completion of this course will help the students to:

- Acquire advanced knowledge in macro and micronutrients
- Understand specific nutrient related situations in population
- Apply the techniques as per the demand of the human nutritional profile.

- Utilize the learning techniques in population education/publication

Suggested Reading

- Bamji MS, Rao NP and Reddy V. 2003. *Textbook of Human Nutrition.* 2nd Edition, Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi.
- Berdanier CD and Zempleni J. 2009. *Advanced Nutrition: Macronutrients, Micronutrients and Metabolism.* CRC Press, New York.
- Eastwood MA. 1997. *Principles of Human Nutrition*. London; Chapman & Hall.
- FAO. 2004. *Human Energy Requirements - Report of a Joint FAO/WHO/UNU Expert Consultation.* Technical Report Series 1. Food and Agriculture Organization, Geneva.
- FAO. 2007. *Protein and Amino Acid Requirements - Report of a Joint FAO/WHO/UNU Expert Consultation.* Technical Report Series 1. Food and Agriculture Organization, Rome.
- Groff JL and Gropper S. 2012. *Advanced Nutrition and Human Metabolism.* 7th Edition, Yolanda Cossio, New York.
- Ross AC, Caballero B, Cousins RJ, Tucker KL and Ziegler TR. 2012. *Modern Nutrition in Health and Disease.* 11th Edition, LWW, Philadelphia.
- Summathi S. 2017. *Food Chemistry and Nutrition.* BS Publication, Hyderabad.
- Whitney EN and Rolfels CR. 2019. *Understanding Nutrition.* 15th Ed., West Publishing Company, USA.
- Wildman REC and Medeiros DM. 2000. *Advanced Human Nutrition*. CRC Press, Boca Raton, Florida.
- Stipanuk MH and Caudill MA. 2013. *Biochemical, Physiological and Molecular Aspects of Human Nutrition.* 3rd Edition, Elsevier Pub.
- https://www.nutritionintl.org
- https://www.who.int
- https://www.hsph.harvard.edu/nutritionsource
- http://www.nin.res.in

Weekly Lecture Schedule

Duration (week)	Topic
1	Body composition. Functions, sources, requirements, digestion and absorption of carbohydrates
2	Composition, classification and functions of dietary fibre
3	Role of dietary fibre, resistant starch and fructo-oligosaccharides in various physiological disorders. Glycemic response to carbohydrates
4	Classification, functions, sources, digestion and absorption of proteins
5	Synthesis of non-essential amino acids in the body. Urea cycle
6	Protein quality
7	Classification, functions, sources, digestion, absorption and deficiency disorders of lipids and essential fatty acids
8	Role of omega-3 fatty acids in physiological disorders
9	Relationship between energy and protein requirements.

	Regulation of food intake. Nutrient adaptation to low intake of energy and protein
10	Functions, absorption, requirement, sources, deficiency and toxicity of fat-soluble vitamins - A, D, E and K
11	Functions, absorption, requirement, sources, deficiency and toxicity of water- soluble vitamins- thiamine, riboflavin, niacin
12	Functions, absorption, requirement, sources, deficiency and toxicity of water- soluble vitamins- pyridoxine, folate, B_{12}
13	Functions, absorption, requirement, sources, deficiency and toxicity of water- soluble vitamins- ascorbic acid, pantothenic acid and biotin
14	Functions, absorption, requirement, sources, deficiency and toxicity of macro minerals – calcium and phosphorus
15	Functions, absorption, requirement, sources, deficiency and toxicity of micro minerals – iron, zinc, sodium, copper, cobalt, selenium and chromium
16	Water and electrolyte balance, functions and distribution of water in body, Electrolyte composition of body fluids and electrolyte balance

Course Code : **FN 502**
Course Title : **Public Health and Nutrition**
Credit Hours : **3(2+1)**

Rationale

This core course on public health nutrition will enable the students with the knowledge in assessment of prevailing nutritional situations of a community across age- sex- physiological conditions. Furthermore, opportunities in analysing Public Health consequences in in-situ conditions will empower the students in planning, executing and evaluating the health and nutrition related development schemes of GOs, NGOs and allied bodies to suggest remedial pathways.

Aim of the course

- To provide both theory and practical exposure to the students on the subject of Public Health Nutrition
- To make them skilled in management of adequate nutritional statures of the population conducive to National Development.

Theory

Unit I: Nutritional status assessment

Assessment of nutritional status at individual, household and institutional level: direct and indirect methods; Ecological, socio-cultural, economic and demographic correlations of malnutrition.

Unit II: Nutritional deficiencies and life style disorders

Prevalence, aetiology, biochemical and metabolic changes in protein energy malnutrition, vitamin A deficiency, iron deficiency anaemia, iodine deficiency disorders, diabetes mellitus, cancer, hypertension and other life style disorders.

Unit III: Present scenario of nutritional problems

Major nutritional problems of the state, nation and world; Nutrition intervention-definition, importance, methods of nutrition intervention, monitoring and evaluation; E-surveillance.

Unit IV: Nutritional programmes and polices

National nutritional programmes and policies and nutritional surveillance; National programmes and policies regarding food production and distribution.

Practicals

1-3. Techniques of assessment of nutritional status
4-5. Use of Screening Tools
6-7. Visit to the ongoing public health nutrition programme and report writing.
8-9. Study of existing diet and nutrition practices
10-12. Planning and conducting survey
13-14. Analysing data and writing report
15-16. Development, implementation and evaluation of community nutrition and health programmes

Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- On field case identification and analysis
- Project planning and report writing

Learning Outcome

Completion of this course will enable the students to take responsibilities as:

- Nutrition educator
- Health educator
- Extension worker for situational analysis of prevailing public health nutritional problems for cultural adaptation strategies.
- Planner and executor of developmental schemes
- Applied researcher

Suggested Reading

- Bamji MS, Kamala K and Brhmam GNV. 2017. *Textbook of Human Nutrition.* 4th Edition, Oxford & IBH.
- Endres JB. 1990. *Community Nutrition Challenges and Opportunities*. Pearson Education
Inc. London.
- Frank GC. 2008. *Nutrition: Applying Epidemiology to Contemporary Practice* . 2nd Edition, Jonts and Bartlett Publishers, Sadbury, MA.
- Gopaldas T and Seshadari S. 1987. *Nutrition Monitoring and Assessment*. Oxford University Press.
- Jeannette BE. 1990. *Community Nutrition: Challenges and Opportunities.* 1st Edition, Merrill.
- Jelliffe DB. 1966. *The Assessment of the Nutritional Status of the Community*. WHO, Geneva.
- Longwah T, Ananthan R, Bhaskarachary K and Venkalah K. 2017. *Indian Food Composition Tables*. National Institute of Nutrition, Hyderabad.
- Marie AB and David HH. 2012. *Community Nutrition in Action: An Entrepreneurial Approach*, Cengage Learning Inc. USA.
- McLaren DS. 1977. *Nutrition in the Community*. John Wiley & Sons.
- Park JE and Park K. 2007. *Park's Text Book of Preventive and Social Medicine.*

19th Edition, Banarsidas Bhanot Publishers, Jabalpur.

- Park JE and Park K. 2017. *Park's Textbook of Preventive and Social Medicine.* Banarsidas Bhanot Publ.
- Prabha B. 2017. *Community Nutrition in India.* 1st Edition, Star Publications, Agra.
- Rosalind S Gibson. 2005. *Principles of Nutritional Assessment.* 2nd Edition, Oxford University Press Inc.
- Salil S and Rita SR. 2007. *Textbook of Community Nutrition.* ICAR publication, New Delhi.
- Shukla PK. 1982. *Nutritional Problems of India.* Prentice Hall of India.
- Suryatapa Das. 2018. *Textbook of Community Nutrition.* 3rd Edn., Academic Publishers.
- https://www.india.gov.in/ agriculture
- https://mhrd.gov.in/mid-day-meal
- https://www.harvestplus.org
- https://www.icmr.nic.in/

Weekly Lecture Schedule

Duration (week)	Topic
1	Assessment of nutritional status at individual, household and institutional level: direct and indirect methods
2	Ecological, socio-cultural, economic and demographic correlations of malnutrition
3	Prevalence, etiology, biochemical and metabolic changes in Vitamin A deficiency
4	Prevalence, etiology, biochemical and metabolic changes in Protein Energy Malnutrition
5	Prevalence, etiology, biochemical and metabolic changes in Iron Deficiency Anaemia
6	Prevalence, etiology, biochemical and metabolic changes in Iodine Deficiency Disorders
7	Prevalence, etiology, biochemical and metabolic changes in Diabetes Mellitus
8	Prevalence, etiology, biochemical and metabolic changes in Hypertension
9	Prevalence, etiology, biochemical and metabolic changes in Cancer and other life style disorders
10	Major nutritional problems of the state, nation and world
11	Nutrition intervention- definition, importance, methods of nutritional intervention, monitoring and evaluation
12	Methods of nutritional intervention, monitoring and evaluation
13	E-surveillance
14	National nutritional programmes and policies and nutritional surveillance
15	National programmes and policies regarding food production
16	National programmes and policies regarding food distribution

Course Code **: FN 503**
Course Title **: Techniques in Food Anaysis**
Credit Hours **: 3 (1+2)**

Rationale

Food analysis is the discipline that deals with the development, application and study of analytical procedures for characterizing the properties of foods and their constituents. It provides analytical data on the quality of a food or product.

Aim of the course

- To provide the students an opportunity to develop precision with the principles, techniques and application of different methods analysis for varied food and products.
- To equip the students with knowledge to ascertain quality of the tested food/ products.

Theory

Unit I: Sampling techniques

Preparation of various standard solutions; Sample and sampling techniques; Introduction to standard analytical methods of FSSAI.

Unit II: Analytical techniques

Principle, techniques and applications of colorimeter, spectrophotometer and atomic absorption spectrophotometer, gel filtration and ultra-centrifugation.

Unit III: Photometric methods and electrophoresis

Principle, techniques and applications of fluorimetry, flame photometry and electrophoresis.

Unit IV: Chromatography

Principle, techniques and applications of paper, thin layer, gas liquid and high-pressure liquid chromatography, introduction to animal assay.

Practicals

1-2. Principles and operation of laboratory equipmen
3-6. Determination of moisture content and titratable acidity
7-8. Determination of ash- dry and wet ash
9-10. Determination of reducing sugars and total sugars
11-14. Analysis of protein- Kjeldhal method
15-16. Analysis of amino acids- HPLC
17-20. Analysis of fat - Soxhlet method, Cold extraction method
21-22. Determination of peroxide value and iodine value
23-24. Analysis of crude fibre. Analysis of minerals- sodium and potassium
25-26. Analysis of iron, copper, zinc and lead. Absorption spectrophotometry
27-28. Analysis of phosphorus- Colorimeter method
29-30. Analysis of vitamin C
31-32. Estimation of carotene. Experiments on gel electrophoresis

Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Group activities
- Hands on training

Learning Outcome

Successful completion of this course will enable the students to:

- Utilize the methods and tools to cater the needs of food analysis
- Guide the process of quality control
- Act as trained food analyst

Suggested Reading

- AOAC. 1995. *Association of Official Analytical Chemists*. Washington, DC. Gruenwedels DW and Whitakor JR. 1984. *FoodAnalysis: Principles and Techniques.* Vols. I-VIII. Marcel Dekker.
- AOAC International. 2016. *AOAC Official Methods of Analysis.* 20th Edition, Association of Official Analytical Chemists. Washington DC.
- Dennis D Miller. 1998. *Food Chemistry*: *A Laboratory Manual*. John Wiley and Sons Indianapolis.
- Joslyn MA. 1970. *Methods in Food Analysis: Physical, Chemical and Instrumental Methods of Analysis.* Academic Press.
- Kalia M. 2002. *Food Analysis and Quality Control.* Kalyani Publishers, New Delhi.
- Neilsen SS. 2010. *Food Analysis.* 4th Ed., ISBN 978-1-4419-1478-1 Springer Science+ Business Media, LLC, USA.
- Neilsen SS. 2002. *Introduction to Chemical Analysis of Foods.* 1st Ed., J S Offset Printers, Delhi.
- Raghuramulu N, Mahavan and Kalyanasundaram SK. 2003. *A Manual of Laboratory Techniques.* 2nd Edition, NIN Press, Hyderabad.
- Sadasivam A and Manickam A. 2004. *Biochemical Methods.* 2nd Edition, New Age International Publishers, New Delhi.
- Sawhney SK and Singh R. 2000. *Introductory Practical Biochemistry*. Narosa Publishing House, New Delhi.
- Veerakumar L. 2006. *Bio-instrumentation*. MIP Publishers. Chennai.
- Pomeranz Y and Molean CE. 1977. *Food Analysis Theory and Practice*. AVI Publ.
- Wood R, Foster L, Damand A and Key P. 2004. *Analytical Methods for Food Additives*. CRC Press, London.
- https://www.fssai.gov.in
- http://www.fda.gov/food/default.htm

Weekly Lecture Schedule

Duration (week)	Topic
1	Preparation of various standard solutions
2	Sample and sampling techniques
3	Sample and sampling techniques
4	Introduction to standard analytical methods of FSSAI
5	Principle, techniques and applications of colorimeter
6	Principle, techniques and applications of spectrophotometer
7	Principle, techniques and applications of atomic absorption spectrophotometer
8	Principle, techniques and applications of gel filtration
9	Principle, techniques and applications of ultra-centrifugation
10	Principle, techniques and applications of fluorimetry

11	Principle, techniques and applications of flame photometry
12	Principle, techniques and applications of electrophoresis
13	Principle, techniques and applications of paper and thin layer chromatography
14	Principle, techniques and applications of gas liquid chromatography
15	Principle, techniques and applications of high-pressure liquid chromatography
16	Introduction to animal assay

ourse Code: FN 504
Course Title : Diet Therapy
Credit Hours : 3 (2+1)

Rationale

Dietetics is a science and art that deals with the optimum nutrition during normal life cycles and its adaptations during ailments. In any situation of life, optimum nutrition can ensure health, endurance, cognition and productivity. As educators/ advisors, the professionals need to equip themselves with the knowledge and skills of managing foods particularly during illness as people's mental condition remains at low ebb in ailment.

Aim of the course

- To provide both theory and practical knowledge on disease management through appropriate approaches with the most recent scientific input from researchers
- To approach the subject from a multidisciplinary perspective - technical, psycho- social-economic of client, drug diet interaction, etc, enabling the students to become effective member Health Care Team (HCT) in Medical Nutrition Therapy (MNT).

Theory

Unit I: Significance of diet therapy

Importance and scope of diet therapy; Role of dietician in a health care team in hospital and community.

Unit II: Dietary management of nutritional disorders

Newer concepts in dietary management of various nutritional disorders and disease conditions; fevers and infections.

Unit III: Dietary management of diseases

Dietary management during burns, allergy, gastrointestinal disorders, liver diseases, cardiovascular diseases, hypertension, renal disorders, obesity, diabetes, cancer and HIV; Nutrition in critical care.

Unit IV: Nutrigenomics and nutraceuticals

Nutrigenomics. Nutraceuticals. Health foods and supplements; Health foods and supplements; Dietary recommendations for blood donors; Nutrients and drug interaction.

Practicals

1. Formulation of food exchanges
2. Therapeutic modifications of diet in terms of nutrients, consistency and composition
3. Planning and preparation of diet for diabetes

4-5. Planning and preparation of diet for cardiovascular diseases

6-7. Planning and preparation of diet for kidney disorders
8. Planning and preparation of diet for obesity
9. Planning and preparation of diet for cancer patients
10. Planning and preparation of diet for burns patients -first, second and third-degree burns
11-12. Planning and preparation of diet for gastrointestinal disorders
13. Planning of diet for critical care patients
14. Visits to hospital to see preparation of tube feeding diets
15-16. Presentation of case studies

Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- Case studies
- Hands on training

Learning Outcome

After completion of this course, the students are expected to:

- Appreciate the scientific foundation of disease management through diet
- Utilize the techniques and tools for assessing the vulnerability of a disease situation towards rejection/ acceptance of the diet suggestion
- Confident responsible member of Healthcare team (HCT) as decision maker

Suggested Reading

- Cataldo CB, De Brayae LK and Whitney EN. 2012. *Nutrition and Diet Therapy*. 6th Edn.,Wadsworth/Thomson Learning Inc.
- Kathleen ML and JL Raymond. 2016. *Krause's Food and the Nutrition Care Process.* 14th Edition, Saunders, Philadelphia.
- Mazur EE and Litch NA. 2018. *Lutz's Nutrition and Diet Therapy.* 7th Edition, F.A. Davis Company, Philadelphia.
- McIntosh SN. 2016. *Williams' Basic Nutrition and Diet Therapy.* 15th Edition, Mosby, Maryland.
- Schlenker E and Gilbert JA. 2014. *Williams' Essentials of Nutrition and Diet Therapy*. 11th edition, e- book.
- Srilakshmi B. 2019. *Dietetics.* 8th Edition, New Age Internatioanal Publisher.
- Skipper A. 2008. *Advanced Medical Nutrition Therapy Practice.* 1st Edition, Jones & Bartlett Learning, Burlington, Massachusetts.
- Ross AC, Caballero B, Cousins RJ, Tucker KL and Ziegler TR. 2012. *Modern Nutrition in Health and Disease.* 11th Edition, LWW, Philadelphia.
- Whitney E, DeBruyne LK, Pinna K and Rolfes SR. 2011. *Nutrition for Health and Health Care.* 4th Edition.
- https://www.nutritionintl.org
- https://www.hsph.harvard.edu/nutritionsource
- https://www.nutrition.org.uk
- http://www.nutritioncare.org

Weekly Lecture Schedule

Duration (week)	Topic
1	New concepts in dietary management of various disorders and diseases, protocols for dietary management
2	Importance and scope of diet therapy. Role of dietician in a health care team in hospital and community
3	Newer concepts in dietary management of fevers and infections
4	Dietary management during burns and allergies
5	Dietary management during gastrointestinal disorders
6	Dietary management during liver diseases
7	Dietary management during obesity
8	Dietary management during hypertension and cardiovascular diseases
9	Dietary management during diabetes
10	Dietary management during renal disorders
11	Dietary management cancer and HIV
12	Nutrition in critical care
13	Nutrigenomics and nutraceuticals
14	Health foods and supplements
15	Dietary recommendations for blood donors
16	Nutrients and drug interaction

Course Code **: FN 505**
Course Title **: Nutrition and Physical Fitness**
Credit Hours **: 3 (2+1)**

Rationale

Physical fitness is a state of health and well-being and more particularly, the capacity to perform satisfactorily in occupations, daily chores and sports. It is generally achieved through proper nutrition, physical exercise and rest. Physical fitness is considered as a measure of body's ability to function efficiently and effectively in work and leisure activities, to be healthy and to resist diseases and to meet emergency situations.

Aim of the course

- To provide both theory and practical exposure to understand the concept of physical fitness
- To incorporate recent techniques of body composition and energy metabolism to ascertain the nutritional stature
- To equip the students with the knowledge and capacity to identify, evaluate and evolve ways in addressing various aspects of physical fitness.

Theory

Unit I: Physical fitness and body composition

Overview of nutritional management vis-à-vis body composition and physical fitness; Techniques to assess physical fitness; Body composition in different physiological conditions and factors affecting it; Methods of measuring body composition.

Unit II: Energy balance

Energy metabolism; Factors influencing energy metabolism and physical fitness; Techniques to measure energy expenditure and energy intake.

Unit III: Sports nutrition

Requirement of nutrients for specific sports events; Exercise physiology and biochemistry; Nutrition support before, during and after sports event; Water and electrolyte requirement during exercise and their role in performance; Ergogenic aids; Definition, types and dosage; Doping: Definition, types and consequences; Muscle physiology for performance and fitness; Biomechanics; Physiological testing for fitness and performance; Strength, flexibility, anaerobic power and cardio respiratory fitness.

Unit IV: Nutrition and ageing

Role of nutraceuticals in fitness; Ageing theories; Physiology, mechanism and role of nutrients in arresting ageing process.

Practicals

1-4. Planning diets for general fitness

5-12. Planning and preparation of diets for different sports categories

13-14. Planning nutritional requirements for sports injuries

15. Visit to a sports academy

16. Visit to established fitness centres

Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Student presentation
- Group activities
- Case studies
- Hands on training

Learning Outcome

On completion of this course, the students will be able to handle responsibilities as:

- Physical fitness educator/ Adviser
- Utilize methods and techniques for vulnerability assessment as per need of the situation
- Experts in Healthcare Team and fitness centres

Suggested Reading

- Benardot D. 2005. *Advanced Sports Nutrition.* 2nd Edition, Human Kinetics Publishers, Champaign, IL.
- Baumgartner R. 2006. *Body Composition in Healthy Aging*. Annals of the New York Academy of Sciences.
- FAO. 2004. *Human Energy Requirements. -Report of a Joint FAO/WHO/UNU Expert Consultation.* Technical Report Series 1. Food and Agriculture Organization, Geneva.
- Geetanjali B and Subhadra M. 2018. *Nutritional Guidelines for Sportspersons*. Jaypee Health Books Publishers.
- Geissler C and Powers H. 2009. *Fundamentals of Human Nutrition.* Churchill Livingstone, London.
- Ross AC, Caballero B, Cousins RJ, Tucker KL and Ziegler TR. 2012. *Modern Nutrition in Health and Disease.* Eleventh Edition, LWW, Philadelphia.
- Srilakshmi B, Suganthi V and Kalaivani C Ashok. 2017. *Exercise Physiology Fitness and Sports Nutrition*. New Age International Publishers.
- https://www.who.int

- https://www.hsph.harvard.edu/nutritionsource
- http://www.nutritioncare.org

Weekly Lecture Schedule

Duration (week)	Topic
1	Concept of physical fitness, recent techniques of body composition and energy metabolism
2	Overview of nutritional management vis-à-vis body composition and physical fitness
3	Methods of measuring body composition
4	Body composition in different physiological conditions and factors affecting it
5	Techniques to assess physical fitness
6	Energy metabolism. Factors influencing energy metabolism and physical fitness
7	Techniques to measure energy expenditure and energy intake
8	Requirement of nutrients for specific sports events
9	Exercise physiology and biochemistry
10	Nutrition support before, during and after sports event
11	Water and electrolyte requirement during exercise and their role in performance
12	Ergogenic aids: Definition, types and dosage
13	Doping: Definition, types and consequences. Muscle physiology for performance and fitness
14	Biomechanics. Physiologic testing for fitness and performance
15	Strength, flexibility, anaerobic power and cardio respiratory fitness Role of nutraceuticals in fitness
16	Ageing theories Physiology, mechanism and role of nutrients in arresting ageing process

Course Code : **FN 506**
Course Title : **Developments in Nutrition and Immunity**
Credit Hours : **2 (2+0)**

Rationale

Immunity is the capability of multi-cellular organism to resist harmful microorganisms from entering it. Good nutrition is essential to build a strong immune system which offers protection from seasonal illness (flu, cold) and other health problems (arthritis, allergies, abnormal cell development, etc.) Students with a good knowledge about role of nutrition in boosting a strong immune system in population will be able to reduce risk factors arising of malnutrition and infection.

Aim of the course

- To impart knowledge about role of various macro and micronutrients along with prebiotics, probiotics and phytochemicals in improving immune systems in the population
- To induce understanding about nutrition and immunity in disease management in age- sex groups across all physiological stages.

Theory

Unit I: Immunity and macronutrients

Immunity: definition and history; Classification of immunity and immunological responses; Role of nutrients in immune functions-Carbohydrates, fat and protein; Effect of arginine, glutamine, sulphur amino acids and omega-3 fatty acids on immune system.

Unit II: Immunity and micronutrients

Effect of deficiency and excess of vitamins and minerals on immune cell functions; Effect of malnutrition on immunity; Infections and undernutrition – causes and consequences and role of immunization.

Unit III: Nutrition during infections

Age related immune depression; Role of nutraceuticals and functional foods in immune system; Nutrition, HIV/AIDS and Tuberculosis.

Unit IV: Immunity and chronic diseases

Nutritional immunity and chronic diseases; Probiotics, prebiotics, phytochemicals and immunity; Food allergy.

Teaching Methods/ Activities

- Lectures
- Assignment (Written/Reading)
- Students' presentations
- Group discussion

Learning Outcome

Completion of the course will enable the students to:

- Understand underlying causes of poor immune system
- Appreciate the scientific foundation for better management of risks associated with poor nutrition and immunity
- Act as confident members in healthcare teams
- Utilize information for publication/ education

Suggested Reading

- Calder P and Yaqoob P. 2013. *Diet, Immunity and Inflammation*. Woodhead Publishing Ltd. Cambridge.
- Gershwin ME, German JB and Keen CL. 2000. *Nutrition and Immunology – Principles and Practice*. Humana Press Inc. New York.
- Gershwin ME, Nestel P and Keen CL. 2004. *Handbook of Nutrition and Immunity*. Humana Press Inc. New York.
- Ivan M Roitt and Peter J Deves. 2004. *Essential Immunology*. Blackwell Science Ltd
- Pammi M, Vallejo JG and Abrams SA. 2016. *Nutrition-Infection Interactions and Impacts on Human Health*. CRC Press, Boca Raton, Florida.
- Philip C Calder and Anil D Kulkarni. 2017. *Nutrition, Immunity, and Infection*. CRC press, London
- Shetty PS. 2010. *Nutrition, Immunity and Infection*. CABI Publishers, Oxfordshire, UK.
- https://www.nutritionintl.org
- https://nutrition.org
- https://www.icmr.nic.in

Weekly Lecture Schedule

Duration (week)	Topic
1	Role of nutrients in maintaining and improving the immunity of

	individuals
2	Immunity: definition, history and classification of immunity and immunological responses
3	Role of nutrients in immune functions- Carbohydrates, fats and proteins
4	Effect of arginine, glutamine, sulphur amino acids and omega-3 fatty acids on immune system
5	Effect of deficiency and excess of vitamins and minerals on immune cell functions
6	Effect of malnutrition on immunity
7	Infections and undernutrition
8	Causes and consequences and role of immunization
9	Age related immune depression
10	Role of nutraceuticals and functional foods in immune system
11	Nutrition in HIV/AIDS
12	Nutrition in Tuberculosis
13	Nutrition, immunity and chronic diseases
14	Probiotics, prebiotics and immunity
15	Phytochemicals and immunity
16	Food allergy

Course Code : FN 507
Course Title : Clinical Nutrition
Credit Hours : 3 (2+1)

Rationale

Clinical nutrition is nutrition of patients in Health care and refers to the management of patients. It incorporates primarily the scientific fields of nutrition and dietetics. Knowledge of striking a positive energy balance in patients along with providing sufficient amount of other nutrients such as proteins, vitamins, minerals is the basis of patient's Health Care Management.

Aim of the course

- To provide both theoretical and applied knowledge on the subject of clinical nutrition for better management of diseases
- To approach various areas of nutrition from a multidisciplinary perspective - biochemical, physiological, pathological and regulatory
- To equip the students to identify the inter-relationship, etiology and management techniques to a specific disease situation including in patients "medical nutrition therapy" understanding to induce situational improvement of health.

Theory

Unit I: Macronutrients

Methods for estimating requirements and recommended allowances of energy, protein, minerals and vitamins for different age groups and physiological state; Growth studies; Depletion and repletion studies; Nutrient balance studies; Use of isotopically labelled nutrients: Nutrient turnover; Obligatory losses of nutrients; National and international recommendations on Nutrient Requirements; Recommendations for Indian by the Indian Council of Medical Research; FAO/ WHO expert committee recommendations; Nutrient interrelationship; therapeutic measures of protein energy malnutrition; Adaptation and chronic energy deficiency; Regulatory processes in chronic energy deficiency; Protein and amino acid turnover; Regulation of amino acid metabolism; Disposal of dietary amino acids and roles of specific organs.

Unit II: Micronutrients

Interrelationship, etiology and preventive measures of vitamin and mineral deficiencies toxicities; Adverse effects of Vitamins and minerals; Upper tolerable levels; Principles and interpretation of clinical laboratory methods with particular emphasis on their interpretation relative to nutritional status and disease; interaction between nutrients, infections and drugs; Functional tests of malnutrition; Nutritional assessment tools in clinical decision making.

Unit III: Nutritional support during disease

Nutritional support, enteral tube feeding, parenteral nutrition, drugs and enteral feeding; Special considerations with nutritional support; Nutrition in surgery and trauma; The stress response to trauma on metabolism; Nutrition support in critically ill patient; Guidelines for use of formula feeds and calculation.

Unit IV: Therapeutic nutrition

Nutrition in GI Diseases; Celiac disease, inflammatory bowel disease, Assessment of liver function - nutritional management in liver disease, acute and chronic pancreatitis, severity scores, nutritional aspects of disease affecting the skeleton, diagnostic imaging, biochemical assessment; Acute and chronic renal failure, nephrotic syndrome, transplantation; Diet and hypertension, stroke, peripheral vascular disease, and chronic heart failure; Wasting syndrome in cancer; Impact of radiation and chemotherapies; Nutritional support on clinical outcomes.

Practicals

1-4. Visit to critical care wards in hospitals for familiarizing with enteral and parenteral feeding methods.

5. Handling and deciphering the medical case sheets.

6-9. Planning enteral feeding, critical care nutritional requirements for different clinical conditions

10-11. Calculating energy, protein, fat and micronutrients after nutritional assessment.

12-13. Presenting case studies of medical cases

14-15. Survey of various enteral feed formulations for different clinical conditions

16. Report writing

Teaching Methods/Activities

- Lectures
- Assignment (writing/reading)
- Students' presentation
- Group activities
- Case studies in medical setup.
- Hands on training

Learning Outcome

After successful completion of this course, the students will be able to

- Appreciate scientific understanding of the clinical situation of a patient and suggesting complementary nutrition therapy for its management
- Utilize methods and tools related to nutrition assessment and advocacy

strategies along with Health Care Team
- Utilize knowledge for scientific Publication
- "Care Education" for target groups
- Utilize the knowledge to act as technical expert in R&D projects

Suggested Reading

- Connie WB and Christine SR. 2016. *Handbook of Clinical Nutrition and Ageing.* Humana Press.
- FAO. 2004. *Human Energy Requirements - Report of a Joint FAO/WHO/UNU Expert Consultation.* Technical Report Series 1. Food and Agriculture Organization, Geneva.
- Gibney MJ, Macdonald IA and Roche HM. 2011. *Nutrition and Metabolism*. Wiley-Blackwell Publishing Company, Boston.
- Gibney MJ, Elia M, Ljungqvist O and Dowsett J. 2013. *Clinical Nutrition*. Wiley-Blackwell Publishing Company, Boston.
- Heimburger DC and Ard JD (2006) *Hand Book of Clinical Nutrition.* Mosby Pub.
- Joshi YK. 2009. *Basics of Clinical Nutrition.* 2nd Edition, Jaypee Brothers Medical Publishers Private Limited, New Delhi.
- Macdonald IA and Michael J Gibney MJ. 2011. *Nutrition and Metabolism*. Wiley-Blackwell Publishing Company, Boston.
- Narasinga Rao BS and Sivakumar B. 2010. *Nutrient Requirements and Recommended Dietary Allowances.* 2nd Edition, National Institute of Nutrition, Hyderabad.
- Marian M and Susan R. 2009. *Clinical/Nutrition for Oncology Patients.* Jones and Bartlett Pub.
- Scott AS and George LB. 1997. *Nutrition Support-Theory and Therapeutics*. Chapman and Hall Series, International Thomson Publications.
- Sharon RR , Kathryn P and Whitney E. 2017. *Understanding Normal and Clinical Nutrition.* Cengage Learning.
- Width M and Reinhard T. 2017. *The Essential Pocket Guide for Clinical Nutrition.* LWW Pub.
- Wayne EB. 2005. *Clinical Nutrition Case Studies.* Cengage Learning.
- Vishwanath S. 2017. *Introduction to Clinical Nutrition.* CRC Press.
- http://www.nutritioncare.org
- https://nutrition.org
- http://www.nutritionlink.org/

Weekly Lecture Schedule

Duration (week)	Topic
1	Methods for estimating requirements and recommended allowances of energy, protein, minerals and vitamins for different age groups and physiological state
2	Growth studies. Depletion and repletion studies. Nutrient balance studies
3	Use of isotopically labelled nutrients: Nutrient turnover. Obligatory losses of nutrients
4	National and international recommendations on nutrient requirements. Recommendations for Indian by the Indian

	Council of Medical Research. FAO/ WHO expert committee recommendations
5	Nutrient interrelationship; therapeutic measures of protein energy malnutrition. Adaptation and chronic energy deficiency. Regulatory processes in chronic energy deficiency
6	Protein and amino acid turnover. Regulation of amino acid metabolism. Disposal of dietary amino acids and roles of specific organs
7	Interrelationship, etiology and preventive measures of vitamin and mineral deficiencies toxicities. Adverse effects of vitamins and minerals. Upper tolerable levels
8	Principles and interpretation of clinical laboratory methods with particular emphasis on their interpretation relative to nutritional status and disease; interaction between nutrients, infections and drugs
9	Functional tests of malnutrition. Nutritional assessment tools in clinical decision making
10	Nutritional Support, Enteral tube feeding, Parenteral nutrition, drugs and enteral feeding
11	Special considerations with nutritional support, Nutrition in surgery and trauma. The stress response to trauma on metabolism
12	Nutrition support in critically ill patient. Guidelines for use of Formula feeds and calculation
13	Nutrition in GI Diseases, celiac disease and inflammatory bowel disease. Assessment of liver function-nutritional management in liver disease, acute and chronic pancreatitis, Severity scores
14	Nutritional aspects of disease affecting the skeleton. Diagnostic imaging, biochemical assessment. The Kidney- Acute, chronic renal failure, Nephrotic syndrome, transplantation
15	Diet and hypertension, stroke, peripheral vascular disease and chronic heart failure
16	Wasting syndrome in cancer. Impact of radiation and chemotherapies. Nutritional support on clinical outcomes

Course Code : **FN 508**
Course Title : **Nutrition Counselling**
Credit Hours : **2 (0+2)**

Rationale

Nutrition counselling is an ongoing process in which nutrition professional works with an individual to assess his/her usual dietary intake to support growth, development and maintenance conducive to good health in normal and ailing conditions. As counsellor, it requires high skill in communication, subject knowledge and understanding the client's socio-eco- cultural background to offer curative/ preventive nutritional advice.

Aim of the course

- To provide ample hands on training to develop skills in communication, application of subject knowledge and understanding client's need and offer curative/ preventing dietary plan in medical or non-medical set-ups

- Tol approach the counselling techniques from and multidimensional perspective i.e. personal, medical, socio-eco cultural good habits and causative factors that contribute to the development of situations affecting normal health of population
- To create effective nutrition counsellors for addressing health and nutritional challenges of population.

Practicals

1-2. Development of resources and dietary guidelines for counselling

3-4. Procedures of nutritional counselling in clinical practice

5-12. Preparing nutritional and dietary care plans for individuals and groups

13-16. Records required for follow up study, group discussion and motivation as tools to
bring attitudinal changes in food selection and preparation

17-18. Exercises on writing scientific facts in simple manner for the people

19-22. Diet campaigns, exhibitions, demonstrations and workshops

23-28. Setting up counselling unit. Counselling in outpatient wards in local hospitals

29-30. Simulation techniques for counselling in selected settings

31-32. Use of dietary apps for counselling and assessing food intake

Teaching Methods/ Assignments

- Hands on training
- Group activities
- Project planning and report writing
- Case studies

Learning Outcome

After successful completion of this practical course, students will be able to:

- Act as confident nutrition counsellor in given setup
- Utilize methods and techniques to correct nutrition related health problems and suggest adaptive strategies in the context of social milieu
- Utilize the scientific knowledge for benefit of the community through population education/ publication
- Act as resource person in handling R&D projects

Suggested Reading

- Aronson V. 1989. *The Dietetic Technician-Effective Nutrition Counselling*. John Wiley and Sons Florida.
- Betsy H and Judith BA. 2014. *Nutrition Counselling and Education Skills for Dietetics Professional.* 6th Edition, LWW, Philadelphia.
- Devito JA. 2015. *Human Communication: The Basic Course*. Pearson, New York.
- Gable J. 2016. *Counselling Skills for Dietitians.* John Wiley and Sons Florida.
- Kathleen DB, Doreen Land Carol AS. 2001. *Basic Nutrition Counselling Skill Development.* Brooks Cole Pub.
- Kathleen DB, Doreen L and Carol AS. 2014. *Nutrition Counselling and Education Skill Development*. CENGAGE Learning Custom Pub, USA.
- King K and Klawitter B. 2007. *Nutrition Therapy. Advanced Counselling Skills*. 3rd Edition, LWW, Philadelphia.

- Mahan LK and Escott S. 2016. *Krause's Food & Nutrition Therapy.* 14th Edition, Saunders, Philadelphia.
- Midwinter R and Dickson J. 2015. *Embedding Counselling and Communication Skills - A Relational Skills Model.* Routledge.
- Snetselaar L. 2009. *Nutrition Counselling Skills for the Nutrition Care Process.* 4th Edition Jones Bartlett Publishers, Sudbury, Massachusetts.
- https://nutrition.org
- http://www.nutritionlink.org
- http://www.fao.org/docrep/X2550E/X2550e04.htm

Course Code : FN 509
Course Title : Food Safety And Standards
Credit Hours : 3 (2+1)

Rationale

Food safety involves the prevention of the adverse effects of chemical substances of food on human beings and means to overcome toxic effect through appropriate processing techniques. It is important to derive maximum benefits of consumed food as far as practicable toxin free.

Aim of the course

- To provide both theoretical and practical exposure to the students on the subject of food safety including types of toxin and methods of removal of these in terms of human health
- To approach the related topics ranging from types, causative factors, signs and symptoms of food toxicity, removal and potential containments
- To induce sufficient knowledge regarding national and international food safety standards.

Theory

Unit I: Xenobiotics

Toxicologically relevant principles of the cell and molecular biology; Dynamics and kinetics of xenobiotics; Environmental pollutants entering the food chain.

Unit II: Food poisoning

Introduction and significance of food toxicology; Food poisoning – types, causative factors, signs and symptoms and preventive measures; Naturally occurring food toxins, their harmful effects and methods of removal.

Unit III: Microbial and chemical toxins

Microbial toxins and food intoxication – source of contamination, effects on health, preventive measures and methods of inactivation and destruction; Chemical toxins – pesticides, insecticides, metallic and others and their residual effects, preventive measures and methods of removal.

Unit IV: Food safety laws and standards

Food packaging material – Potential contaminants from food packaging material; Food safety laws and standards: FSSAI, FPO, ISI, Agmark, Codex Alimentarius, ISO mark for vegetarian and non-vegetarian foods, eco-friendly products and others in operation.

Practicals

1-2. Basic chemical diagnostics of poisonings based on the samples from dead

animal's organs and feed

3-7. Methods of identification and quantification of poisons isolation from biological materials

8-9. Principles of sampling and sending biological materials for toxicological analysis

10. Basis of intravital laboratory diagnostics of acute and chronic poisonings

11. Evaluation of toxic effects concerning the degree and the time of exposure to a xenobiotic

12-13. The determination of cholinesterase activity in the whole blood, in blood plasma and in red blood cells after the exposure to organophosphate and carbaminate insecticides

14. Evaluation of the effect of an antidote

15. Identification of nitrite and nitrate in water and in vegetables

16. Evaluation of nitrite and nitrate effect on haemoglobin.

Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Group activities
- On field case identification and analysis
- Hands on training

Learning Outcome

Successful completion of this course will enable the students to:

- Be an expert on the subject relating key learnings as food safety officer/ extension worker/ food inspector
- Utilize learning in scientific Publications/ population education

Suggested Reading

- Concon JM. 2000. *Food Toxicology- Principles and Concepts - Part A and B.* Marcel-Dekker Inc. New York.
- Helferich W and Winter CK. 2001. *Food Toxicology*. CRC Press, Boca Raton, Florida.
- Pussa T. 2013. *Principles of Food Toxicology*. CRC Press, Boca Raton, Florida.
- Timbrell J. 2001. *Introduction to Toxicology.* 3rd Edition, Informa, London.
- Vought JB and Henderson MK. 2000. *Principles of Sampling and Sending Biological Materials for Toxicological Analysis - Unit II Biomarkers Practical Aspects*. IARC publication, WHO, Geneva.
- https://www.fssai.gov.in
- http://www.fda.gov/food/default.htm

Weekly Lecture Schedule

Duration (week)	Topic
1	Toxicologically relevant principles of the cell and molecular biology
2	Dynamics and kinetics of xenobiotics
3	Environmental pollutants entering the food chain
4	Introduction and significance of food toxicology
5	Food poisoning – types and causative factors
6	Food poisoning- signs and symptoms and preventive measures

7	Naturally occurring food toxins, their harmful effects
8	Naturally occurring food toxins- methods of removal
9	Microbial toxins and food intoxication – source of contamination and effects on health
10	Microbial toxins and food intoxication- preventive measures and methods of inactivation and destruction
11	Chemical toxins – pesticides, insecticides, metallic and others and their residual effects
12	Chemical toxins – Preventive measures and methods of removal
13	Food packaging material- Potential contaminants from food packaging material
14	Food laws and standards: FPO and ISI
15	Agmark, Codex Alimentarius and ISO
16	Mark for vegetarian and non-vegetarian foods, eco-friendly products and others in operation

Course Code : **FN 510**
Course Title : **Nutritional Challenges in Life Cycle**
Credit Hours : **3 (3+0)**

Rationale

Nutrition is crucial for the fulfilment of human rights especially those of the most vulnerable groups i.e. infants, children less than 5 years of age, girls and women who constitute the foundation of human development and national prosperity. Knowing the nutritional challenges during various stages of life cycle can reduce susceptibility to infection, morbidity, disability and mortality, thereby, enhancing cumulative lifelong learning capacities and adult productivity.

Aim of the course

- To give an exposure to the students with an in-depth basic knowledge regarding nutritional challenges of vulnerable groups during various stages of life cycle
- To approach the areas from various angles like nutritional needs of fetus, mothers (expectant and lactating), adolescents, adults and geriatrics in terms of cognitive learning abilities and to remain healthy and productive
- To equip students to identify, evaluate and evolve management techniques to address nutritional challenge.

Theory

Unit I: Importance of maternal nutrition

Nutritional needs during first 1000 days; Influence of maternal nutritional status on outcome of pregnancy: birth weight of infant and lactation performance.

Unit II: Human milk

Psycho-physiology of lactation; Milk synthesis and secretion; Maternal needs during lactation; Composition of colostrum and mature human milk; Milk of mothers of preterm babies; Milk of animal and formula feeds; Non-nutritional factors of human milk - immunological factors, enzymes and hormones; Human milk banking.

Unit III: Nutrition during childhood, adolescence and adulthood

Nutritional needs of the children and adolescents; Common childhood ailments and dietary considerations; Growth spurt and nutrition; Adolescent fads influencing nutrition, food preferences and nutritional problems; Nutritional requirements in adulthood; Malnutrition, mental development, learning abilities and behavior.

Unit IV: Geriatric nutrition

Overview of ageing process; Nutritional variables related to the ageing process; Physiology of aging; Biological markers of aging; Sociology of aging; Nutritional requirements and deficiencies in elderly; Medications and psychiatric problems in elderly; Immunopathological diseases and aging; Parkinson and Alzheimer syndrome; Care of the elderly; Care-givers and community services.

Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Student presentation
- Group activities

Learning Outcome

Successful completion of this course will enable the students to

- Appreciate the scientific understanding of mitigating nutritional challenges and relating key learning as professional expert in the area
- Utilize methods and hand tools for vulnerability assessment and designing adaptation strategies
- Utilize knowledge in scientific publication/ population education
- Be an expert in community health and R&D projects

Suggested Reading

- Bales CW, Ritchie CS. 2013. *Handbook of Clinical Nutrition and Aging.* 2nd Edition, Springer Science & Business Media, Humana Press Inc. New York.
- Cataldo CB, De Brayae LK and Whitney EN. 2012. *Nutrition and Diet Therapy*. 6th Edn., Wadsworth/Thomson Learning Inc.
- Chernoff R. 2003. *Geriatric Nutrition: The Health Professional's Handbook.* 2nd Edition, Jones & Bartlett Learning, Burlington, Massachusetts.
- Kleinman RE. 2008. *Paediatric Nutrition Handbook.* 6th Edition, American Academy of Paediatrics Committee on Nutrition.
- Sachdev HPS and Choudhury P. 2004. *Nutrition in Children - Developing Country Concerns.* B I Publications.
- Schlenker E and Gilbert JA. 2014. Williams' *Essentials of Nutrition and Diet Therapy*. 11th Edition, e- book.
- Sharbaugh C and Brown JE. 2013. *Nutrition Through the Life Cycle.* 5th Edition, Wadsworth Co Inc. Belmont, CA.
- Srilakshmi B. 2019. *Dietetics.* 8th Edition, New Age Internatioanal Publisher.
- Whitney E, DeBruyne LK, Pinna K and Rolfes SR. 2011. *Nutrition for Health and Health Care.* 4th Edition.
- World Health Organization. 2005. *WHO Library Cataloguing-in-Publication Data. Nutrition in Adolescence –Issues and Challenges for the Health Sector.* WHO, Geneva.
- https://www.who.int
- http://www.nutritionlink.org

- https://www.icmr.nic.in

Weekly Schedule

Duration (week)	Topic
1	Nutritional needs of the foetus during different stages of fetal cell growth
2	Maternal nutritional needs
3	Influence of maternal nutritional status on outcome of pregnancy: birth weight of infant and lactation performance
4	Psycho-physiology of lactation. Milk synthesis and secretion
5	Maternal needs during lactation
6	Composition of colostrum and mature human milk. Milk of mothers of preterm babies. Milk of animal and formula feeds
7	Non-nutritional factors of human milk -immunological factors, enzymes and hormones
8	Human milk banking
9	Nutritional needs of the children and adolescents
10	Common childhood ailments and dietary considerations
11	Growth spurt and nutrition. Adolescent fads influencing nutrition, food preferences and nutritional problems
12	Nutritional requirements in adulthood. Malnutrition, mental development, learning abilities and behaviour
13	Overview of ageing process. Nutritional variables related to the ageing process. Physiology of aging. Biological markers of aging. Sociology of aging
14	Nutritional requirements and deficiencies in elderly. Medications and psychiatric problems in elderly
15	Immuno-pathological diseases and aging. Parkinson and Alzheimer syndrome
16	Care of the elderly. Care-givers and community services

Course Code **: FN 511**
Course Title **: Food Science**
Credit Hours **: 3 (2+1)**

Rationale

Food is an integral part of everyone's life. This course will empower the students to understand the science factors of food, effects of different processing methods on its nutritional qualities and how to conserve nutrients to the best benefits of the consumers.

Aim of the course

- To expose the students in understanding the changes in foods during various processing methods in laboratory setups
- To equip the students in understanding the desirable and undesirable effects of food treatments and identify the best ones for the benefit of consumers as food or trade.

Theory

Unit I: Evaluation of food

Colloidal chemistry as related to foods; Evaluation of food by subjective and objective methods.

Unit II: Characteristics of sugars and starches

Carbohydrates in foods sources; Characteristics of sugar; Starches - types, sources, uses and chemical characteristics; Factors effecting viscosity of starch paste; Characteristics of cellulose and pectin; Gums in foods; Effect of cooking and processing techniques on carbohydrates; Batters and dough- types, properties.

Unit III: Processing of cereals, legumes and animal foods

Preparation of gluten structure; Dough changes in baking; Protein in foods: Plant and animal protein; Chemical and physical properties related to protein foods; Effect of cooking and processing techniques on animal foods – meat, fish, poultry, eggs, milk and milk products; Effect of cooking and processing of plant foods – cereals, millets, legumes, nuts and oilseeds;

Unit IV: Processing of fruits and vegetables

Classification and importance of fruits and vegetables; Composition of fruits and vegetables. Effect of cooking and other processing methods on the nutritive value of fruits and vegetables; Food pigments; Browning reactions in fruits and vegetables; Classification and importance of beverages; Definition, classification, uses and legal aspects of food additives; Classification, nature and uses of leavening agents.

Practicals

1. Microscopic structure of different starch granules
2. Evaluation of food by subjective and objective methods

3-4. Changes in colour, texture and flavour of foods due to processing

5. Product preparation using leavening agents
6. Physicochemical evaluation of grains like length, breadth, L/B ratio, bulk density, cooking properties, 1000 grains weight
7. functional properties of grains - gelatinization, water absorption capacity, oil retention capacity and water retention capacity

8-9. Sugar cookery

10. Smoking temperature of fats and oils
11. Factors effecting absorption of fats
12. Deep fat fried food preparation
13. Changes in cookery- meat, fish, poultry
14. Coagulation of egg, poached egg, omelette, custard, cake
15. Emulsion - mayonnaise preparation
16. Soaking, germination and fermentation of pulses

Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- Hand on experience

Learning Outcome

After completion of this course, the students are expected to:

- Appreciate the scientific foundation of food and its application to the benefits of human health
- Perform as Food Analyst
- Become Food Entrepreneurs

- Act as Health/ Nutrition advisor

Suggested Reading

- Belle Lowe. 2019. *Experimental Cookery from the Chemical and Physical Standpoint*. Facsimile Pub.
- Potter NN and Hotchkiss JH. 2007. *Food Science*. 5th Edition, CBS, New Delhi.
- Roday S. 2018. *Food Science and Nutrition.* 3rd Edition, Oxford University Press, UK.
- Sharma A. 2005. *Textbook of Food Science and Technology*. 3rd Edition, CBS, New Delhi.
- Stone H. 2004. *Sensory Evaluation Practices* (*Food Science and Technology*). 3rd Edition, Academic Press, Cambridge.
- Subbalakshmi G and Udipi SA. 2006. *Food Processing and Preservation*. New Age International, New Delhi.
- Sofia Jan. 2013. *Elements of Food Science.* New India Publishing Agency,New Delhi ISBN: 979-93-81450-24-6.
- Vaclavik VA and Christian EW. 2014. *Essentials of Food Science.* 4th Edition, Springer-Verlag, New York.
- https://www.ift.org
- https://www.foodsciencematters
- https://www.ifst.org

Weekly Lecture Schedule

Duration (week)	Topic
1	Colloidal chemistry as related to foods
2	Evaluation of food by subjective and objective methods
3	Carbohydrates in foods sources
4	Characteristics of sugar
5	Starches-types, sources, uses and chemical characteristics
6	Factors effecting viscosity of starch paste
7	Characteristics of cellulose and pectin. Gums in foods
8	Effect of cooking and processing techniques on carbohydrates. Batters and dough- types, properties
9	Preparation of gluten structure. Dough changes in baking
10	Protein in foods: Plant and animal protein. Chemical and physical properties related to protein foods
11	Effect of cooking and processing techniques in Animal foods – meat, fish, poultry, eggs, milk and milk products
12	Effect of cooking and processing of plant foods – cereals, legumes, nuts and oilseeds
13	Classification and importance of fruits and vegetables. Composition of fruits and vegetables
14	Effect of cooking and other processing methods on the nutritive value of fruits and vegetables. Food pigments. Browning

	reactions in fruits and vegetables
15	Classification and importance of beverages. Definition, classification, uses and legal aspects of food additive
16	Classification, nature and uses of leavening agents

Course Code : **FN 512**
Course Title : **Food Processing Technology**
Credit Hours : **3(2+1)**

Rationale

Almost all foods consumed need processing from field to plate. While some processing is applicable to day- to- day life to consume safe and healthy foods, most of the perishable foods require special techniques to conserve nutrients alongside increasing shelf life. Knowledge of the subject is an integral part for food entrepreneurs.

Aim of the course

- To give exposure of the subject, with the newer techniques in food processing procedures ranging from preliminary steps to the packaging aspects of different foodstuff for safe consumption and business
- To equip students to identify and application of processing methods suitable to meet the purpose of the consumer.

Theory

Unit I: Food processing techniques

Principles underlying food processing operations including thermal, radiation, refrigeration freezing and dehydration; Effect of processing on physiochemical characteristics; Principles underlying pressure modified processing (high hydrostatic pressure, hyperbaric processing, vacuum cooling, hypobaric storage).

Unit II: Processing technologies for plant foods

Processing technology for preservation and production of variety food products during storage, handling and processing of cereals/millets and legumes, oilseeds, fruits and vegetables; Food preservation by Hurdle technology and canning technology.

Unit III: Processing technologies for animal foods

Processing technology for milk and milk products, egg, meat, poultry and fish, convenience foods and processed foods; Technologies underlying mutual supplementation, enrichment and fortification, fermentation, malting and germination; Food additives commonly used in food industries for colour, flavour and as preservatives; Nanomaterials as food additives.

Unit IV: Quality control in food processing

Quality control in food industry - raw materials and finished products; Waste management and sanitation in food industries; Packaging - self-cooling self-heating packaging, micro packaging, antimicrobial packaging and water-soluble packaging.

Practicals

1. Effect of blanching on enzymatic activity and volume occupation
2. Effect of refrigeration and freezing on quality of fruits and vegetables
3. Dehydration of fruits and vegetables
4. Canning of fruits and vegetables

5-6. Preparation of fruit candy, squash, nectar, malt beverages and quality evaluation with respect to FPO
8. Clarification of juice using various methods (chemical, enzyme and fining agents)
8-9. Malting of green gram, moth bean- enzymatic activity determination
10. Preparation of *Paneer* and curd and its quality evaluation
11. Quality evaluation of egg and fish
12. Effect of chemical preservation on storage quality of food (bread, cake).
13. Storage of nuts and oil seeds under vacuum packaging
14. Packaging of fruits and vegetables for transportation distance market using corrugated fibre boxes
15. Transportation of fresh fruits and vegetables using cushioning system and fibre board
16. Visit to food processing unit

Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Group activities
- Hands on training

Learning Outcome

This course will help students to

- Utilize the scientific knowledge to become food processing entrepreneur
- Utilize the acquired knowledge for being an expert in any Processing Unit
- Assist in ascertaining quality control of a consumed food in any given situation

Suggested Reading

- Brennan JG. 2006. *Food Processing Handbook*. Wiley-VCH
- Clark S, Jung S and Lamsal B. 2014. *Food Processing - Principles and Applications.* 2nd Edition, Wiley-Blackwell Publishing Company, Boston.
- Fellows PJ. 2000. *Food Processing Technology*. Woodhead Publishing Ltd.
- Fellows PJ. 2017. *Food Processing Technology, Principles and Practice.* 4th Edition, Woodhead Publishing Ltd. Cambridge.
- Hartel R W and Heldman D. 2012. *Principles of Food Processing*. Aspen Publishers Inc. New York.
- Owens G. 2001. *Cereals Processing Technology*. Woodhead Publishing Ltd.
- Sivshankar B. 2002. *Food Processing and Preservation*. Prentice-Hall of India Pvt. Ltd. Delhi.
- Subbalakshmi. 2001. *Food Processing and Preservation*. New Age International Publishers, New Delhi.
- Vaclavik V. 2018. *Dimensions of Food.* CRC Press.
- https://www.ift.org
- https://www.foodsciencematters
- https://www.ifst.org

Weekly Lecture Schedule

Duration (week)	Topic
1	Principle underlying food processing operations including thermal, radiation, refrigeration, freezing and dehydration
2	Effect of processing on physiochemical characteristics

3	Principles underlying pressure modified processing (high hydrostatic pressure, hyperbaric processing, vacuum cooling, hypobaric storage)
4	Processing technology for preservation and production of variety food products during storage, handling and processing of cereals, legumes and oilseeds
5	Processing technology for preservation and production of fruits and vegetables
6	Food preservation by Hurdle technology
7	Food preservation by canning technology
8	Processing technology for milk and milk products, egg, meat, poultry and fish
9	Processing technology for convenience foods and processed foods
10	Technologies underlying in mutual supplementation, enrichment and fortification
11	Technologies underlying fermentation, malting and germination
12	Food additives commonly used in food industries for colour, flavour and as preservatives
13	Nanomaterials as food additives
14	Quality control in food industry - raw materials and finished products
15	Waste management and sanitation in food industries
16	Packaging - self-cooling self-heating packaging, micro packaging, antimicrobial packaging and water-soluble packaging

Course Code : **FN 513**
Course Title : **Human Physiology**
Credit Hours : **3 (3+0)**

Rationale

Physiology is the scientific study of the function and mechanism which work within a living system. Human Physiology seeks to understand the mechanisms that work to keep the human body alive and functioning through scientific enquiry to keep humans healthy and productive. Changes in Physiology in human can impact vital body functions.

Aim of the course

- To give theoretical concepts to complex physiological systems of the human body through scientific enquiry into the nature of mechanical, physical and biochemical function of humans, their organs and cells of which they are composed
- To approach the subject area from variegated angles to equip the students with the knowledge of importance of normal and altered picture of biological markers and suggest remedies.

Theory

Unit I: Circulatory system

Overview of anatomy and functions of human body; Reticuloendothelial system- functions, classification; Lymphatic system- functions, circulation; Circulatory system- blood and composition blood cells, development and function of blood cells, blood clotting, blood grouping and haemoglobin, Heart - anatomy, cardiac cycle, blood pressure and factors affecting blood pressure.

Unit II: Respiratory system

Respiratory system- anatomy, physiology and mechanism of respiration, regulation of respiration; Digestive system- anatomy of gastrointestinal tract and accessory organs, digestion and absorption of food, regulation of appetite.

Unit III: Excretory system

Excretory system- anatomy and functions of kidney, formation, composition and excretion of urine; Endocrine glands, mode of action of hormones.

Unit IV: Reproductive system

Reproductive system- structure and functions of male and female reproductive organs; Anatomy and functions of nervous and musculoskeletal system.

Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities

Learning Outcome

This course will help students to:

- Apply knowledge in understanding interrelationship between physiology and nutrition.
- Enable to act as a reliable team member in Healthcare team in medical and non-medical setups.
- Apply the acquired techniques for population education

Suggested Reading

- Chaterjee CC. 2012. *Human Physiology Vol. I and Vol. II.* CBS Publications.
- David F, Stacia BM and Charles LS. 1993. *Human Physiology- Foundations and Frontiers.* 2nd Edn., Mosby Pub.
- Donnersberger AB and Scott AL. 2005. *Laboratory Textbook of Anatomy and Physiology*. 8th Edition, Jones and Bartlett Learning, Burlington, Massachusetts.
- Jain AK. 2009. *Human Physiology for BD.* 3rd Edition, Avichal Publishing Company, New Delhi.
- Hall JE. 2016. *Gayton and Hall Text Book of Medical Physiology*. 13th Edition, Elsevier India.
- Marieb EN. 2004. *Human Anatomy and Physiology 6th Edition.* Pearson Education, Inc. London.
- Waugh A and Grant A. 2014. *Ross and Wilson Anatomy and Physiology in Health and Illness.* 6th Edition, Elsevier Ltd. Churchill Livinstone, London.
- http://novella.mhhe.com/sites/0073525707/information_center_view0/custom_publishing_ primis.html
- https://jsums.instructure.com/courses/2144344/pages/welcome-to-holes-human-

anatomy- and-physiology-11-slash-e

Weekly Lecture Schedule

Duration (week)	Topic
1	Overview of anatomy and functions of human body
2	Reticuloendothelial system- functions, classification
3	Lymphatic system- functions, circulation
4	Circulatory System- blood and composition blood cells, development and function of blood cells
5	Blood clotting, blood grouping and haemoglobin
6	Heart – anatomy and cardiac cycle
7	Blood pressure and factors affecting it
8	Respiratory system- anatomy and physiology
9	Mechanism of respiration and its regulation
10	Digestive system- anatomy of gastrointestinal tract and accessory organs
11	Digestion and absorption of food, regulation of appetite
12	Excretory system- anatomy and functions of kidney
13	Formation, composition and excretion of urine
14	Endocrine glands, mode of action of hormones
15	Reproductive system- structure and functions of male and female reproductive organs
16	Anatomy and functions of nervous and musculoskeletal system

Course Code : **FN 514**
Course Title : **Institutional Food Service Management**
Credit Hours : **2 (1+1)**

Rationale

Institutional food Service Management denotes the entities that provides meals at educational institutes, hospitals, care homes, hotels, public and private cafeteria, etc. Students equipped with updated knowledge in this area will help them to act as an expert to suggest quality food to the customer as per their needs.

Aim of the course

- To equip the students with the multi-dimensional knowledge associated with institutional food service in a given setup
- To enable them in planning, execution and control of the management of institutes with ease and profit.

Theory

Unit I: Food service management

Types of food services - organization and management. Tools of management; FSSAI and CODEX guidelines.

Unit II: Record keeping

Personnel management; Books, records and record keeping; Cost control in food services; Menu planning; HACCP.

Unit III: Quantity food production

Meal services management; Types of services; Quantity food production; Principles involved in development of recipes in large scale cooking; Standardization of recipes; Utilization of left-over foods.

Unit IV: Planning of food service unit

Types of kitchens; Planning of layout and equipment for food services; Sanitation and hygiene in handling foods; Personnel hygiene and its importance; Organisation of spaces.

Practicals

1-2. Standardization of basic recipes: planning and preparation
3. Modification in basic recipes
4. Use of left-over foods
5-6. Visit to different types of food service institutions and study the organization, physical plan and layout, food service equipment, sanitation and hygiene.
7-10. Practical experience in organization and management of a college cafeteria/ hotels
11-12. Setting of canteens with formal and informal table setting
13. Scale production of standardised recipes
14-15. Menu planning for snack bars, canteens, residential hostels and hospitals
16. Cost analysis

Teaching Methods/ Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group activities
- Hands on training

Learning Outcome

This course will help students to:

- Act as front office managers
- Skilled in centralized/ decentralized service providers in medical/ care homes
- Skilled chef and service providers

Suggested Reading

- Arora RS. 2012. *Banquet and Catering Management.* Abhijeet Publications.
- Beckley JH, Herzog LJ and Foley MM. 2017. *Accelerating New Food Product Design and Development.* 2nd Edition, John Wiley and Sons Inc. Hoboken, New Jersey.
- Carpenter RP, Lyon DH and Hasdell TA. 2002. *Guidelines for Sensory Analysis in Food Product Development and Quality Control.* 2nd Edition, Aspen Publishers Inc. New York.
- Earle M and Earle RL. 2008. *Case Studies in Food Product Development.* Woodhead Publishing Limited and CRC Press, New York.
- Harish Bhat. 2008. *Hotel Management.* Crescent Publishing Corporation.
- Moskowitz HR, Straus T and Saguy S. 2009. *An Integrated Approach to New Food Product Development.* CRC Press, Boca Raton, Florida.
- Mudit Bhajwani. 2007. *Food Service Management: Principles and Practice.* Rajat publications, New Delhi.
- Nancy LS. 2007. *Catering Management*. John Wiley & Sons.
- Puckett RP. 2012. *Food Service Manual for Health Care Institutions.* 4th Edition, John Wiley and Sons Inc. Hoboken, New Jersey.

- Sethi M. 2018. *Catering Management- An Integral Approach.* 3rd Edition, New Age International, New Delhi.
- https://www.ferrerofoodservice.com
- https://www.foodservicedirector.com
- Vaclavik V (2018) *Dimensions of Food*. CRC Press.

Course Title with Credit Load for Ph.D in Community Science – Food & Nutrition

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
FN 601*	Macronutrient Metabolism	3(3+0)
FN 602*	Micronutrient Metabolism	2(2+0)
FN 603*	Nutrition and Agricultural Interface	3(3+0)
FN 604	Global Nutritional Problems	2(2+0)
FN 605	Nutrition in Calamities	2(2+0)
FN 606	Maternal and Child Nutrition	2(2+0)
FN 607	Hormones and Enzymes	2(2+0)
FN 608	Energy Metabolism	2(2+0)
FN 609	Application of Biotechnology in Food Science and Nutrition	3(3+0)
FN 610	Recent Trends in Food Science and Technology	3(3+0)
	Minor Courses (06 Credits)	
FN 515	Food Science and Technology	3(2+1)
FN 516	Food Biochemistry	3(2+1)
FN 517	Nutritional Biochemistry	2(2+0)
FN 518	Food Microbiology	3(2+1)
EECM 603	Scaling Techniques for Behaviour Research	3(1+2)
EECM 605	Sustainable Livelihood Systems	2(1+1)
	Supporting Courses (05 Credits)	
FN 691	Doctoral Seminar I (Major Field)	1(1+0)
FN 692	Doctoral Seminar I (Minor Field)	1(1+0)
FN 699	Research	75
	T O T A L	**100**

*Core Courses/Compulsory Courses

Course Code : **FN 601**
Course Title : **Macronutrient Metabolism**
Credit Hours : **3(3+0)**

Rationale

Food intake is sporadic: for most people it occurs in three major boluses each day. Energy expenditure, however, is continuous, with variations during the day that bears no resemblance to the energy intake pattern. Macronutrients are the three sources of energy which are variably stored and assimilated from food each day. A basic understanding of this fact will help the students to address the need of efficient energy metabolism in people to maintain energy balance for health. Furthermore, it will help to guide people how to lessen the food related disease burden like obesity, Type 2 diabetes, heart disease, etc.

Aim of the course

- To give a strong theoretical base to the students with reference to metabolism of macronutrients
- To approach the related areas from a multidimensional perspective—digestion, absorption, assimilation and metabolism in relation to normal health maintenance and preventing disease onsets
- To equip the students to identify, stratify and manage the risks associated with energy metabolism.

Theory

Unit I: Macronutrients

Digestion, absorption and metabolism of carbohydrates, proteins and lipids; Inborn errors of metabolism; Degenerative diseases - diabetes, obesity, atherosclerosis, hyperlipidaemia and hypertension; Glucose homeostasis determined by insulin/ glycogen ratio; low carbohydrates diet and its metabolic consequences.

Unit II: Dietary fibre

Glycaemic Index and load; Dietary fibre and its impact in various physiological disorders; Hypoglycaemic action of foods.

Unit III: Proteins

Classification of protein, new discoveries in protein and their functions (protein in immune system, biological buffers and carriers); Evaluation of protein quality- *in vitro* and *in vivo* methods, animal and human bioassays; Amino acid pool, protein turnover in man with special reference to body size, age and various nutrition and pathological conditions; Novel food sources of protein; Role of hormones in protein metabolism; Effect of dietary protein on cardiovascular disease and cholesterol metabolism; Adaptation of body to low intake of energy and protein.

Unit IV: Lipids

Hypolipidemic action of MUFA, PUFA and oxidation products of cholesterol; Effect of saturated fatty acids and trans fatty acids in lipid metabolism, role of reversal diet in cardiovascular disorders; Causes, prevention and treatment of hyperlipidaemia.

Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Student presentation

- Online Group Discussion

Learning Outcome

After successful completion of this course, the students will be able to

- Appreciate the scientific knowledge in the process of energy metabolism
- Utilize the methods and tools for the management of hypo/hyper metabolic stages
- Utilize knowledge for scientific deliberations
- Act as Clinical Nutritionist in medical set-ups
- Expert Member of Health Care Team (HCT)
- Researcher in related R&D Projects

Suggested Reading

- Akoh CC and Min DB. 2002. *Food Lipids - Chemistry, Nutrition and Biotechnology*. Marcel Dekker Inc. New York.
- Dickens F. 1981. *Carbohydrate Metabolism and its Disorders Vol. III*. Academic Press, Cambridge.
- FAO WHO/UNU ý(2004ý) *Human Energy Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation*. Geneva: World Health Organization. FAO Food and Nutrition Technical Report Series 1.
- FAO WHO/UNU. ý2007. *Protein and Amino Acid Requirements in Human Nutrition: Report of a Joint FAO/WHO/UNU Expert Consultation, Geneva*. Word Health Organization. Technical Report Series 935. http://www.who.int/iris/handle/10665/43411.
- Nelson D L and Cox MM. 2017. *Lehninger Principles of Biochemistry.* 7th Edition. WH Freeman, New York.
- Stipanuk MH and Caudill MA. 2013. *Biochemical, Physiological and Molecular Aspects of Human Nutrition.* 3rd Edition. Elsevier Pub.
- https://www.who.int
- http://www.fao.org/home/en
- https://www.nutrition.org.uk

Weekly Lecture Schedule

Duration (week)	Topic
1	Carbohydrates -digestion, absorption and metabolism. Proteins - digestion, absorption and metabolism. Lipids- digestion, absorption and metabolism
2	Inborn errors of metabolism. Diabetes
3	Obesity
4	Atherosclerosis
5	Hyperlipidaemia
6	Hypertension
7	Glucose homeostasis determined by insulin/glycogen ratio. Low carbohydrates diet and its metabolic consequences
8	Glycaemic Index and load. Dietary fiber and its impact in various physiological disorders
9	Hypoglycemic action of foods. Classification of protein
10	New discoveries in protein and their functions in immune system, biological buffers and carriers
11	Evaluation of protein quality- *in vitro* and *in vivo* methods, animal and human bioassays

12	Protein turnover in man with special reference to body size, age and various nutrition and pathological conditions. Novel food sources of protein
13	Role of hormones in protein metabolism. Effect of dietary protein on cardiovascular disease and cholesterol metabolism. Adaptation of body to low intake of energy and protein
14	Hypolipidemic action of MUFA, PUFA and oxidation products of cholesterol
15	Effect of Saturated fatty acids and trans fatty acids in lipid metabolism. Role of reversal diet in cardiovascular disorders
16	Causes, Prevention and treatment of hyperlipidemia

Course Code : **FN 602**
Course Title : **Micronutrient Metabolism**
Credit Hours : **2(2+0)**

Rationale

Micronutrients are required by human and other organisms all over life in small quantities to coordinate a wide range of physiological functions. While vitamins are chiefly necessary for energy production, immune functions, blood clotting, etc. the minerals play important role in growth, bone health, fluid balance, etc. An advanced understanding of the metabolism aspects of these nutrients will enable the students to guide the population in encouraging proficient metabolic stages in humans to address the public health nutritional problems.

Aim of the course

- To give a strong theoretical understanding of the essentiality of micronutrient sufficiency to aid metabolic processes in relation to health and disease onset
- To enhance the knowledge of recent advances in micronutrient nutrition that will help the students to plan and execute policies in micronutrient malnutrition in population.

Theory

Unit I: Vitamins

History, chemistry, distribution and functions of vitamins; Absorption, transportation, metabolism of vitamins; Nutritional requirements of vitamins; Deficiency manifestations of water soluble vitamins; Deficiency manifestations of fat soluble vitamins; Causes of vitamin deficiencies in India; Hypervitaminosis of water-soluble vitamins; Hypervitaminosis of fat-soluble vitamins; Vitamin fortification and supplementation; Methods of assay of vitamins; Interaction with other nutrients, antagonists and analogues of vitamins; Assessment of vitamin status of population.

Unit II: Minerals

Causes of macro and micro mineral deficiencies in India; Chronology, chemistry and distribution of minerals; Functions, absorption, transport and metabolism of minerals; Deficiency manifestations of minerals; Nutritional requirements of minerals; Methods of assay of minerals; Interactions of minerals with other nutrients, antagonists and analogues of minerals; Assessment of mineral status of population; Mineral fortification and supplementation; Metaloenzymes. Antioxidants and their relationship with aging, cancer and various non-communicable diseases.

Unit III: Heavy metal toxicity

Harmful effects of major mineral pollutants on health - mutagenicity, carcinogenicity and heavy metal toxicity; Heavy metal toxicity;

Unit IV: Trace elements

Trace minerals - their chronology, chemistry, distribution. Functions of trace minerals. Absorption and metabolism of trace minerals. Requirements of trace minerals. Deficiency manifestation and interaction of trace minerals. Use of mineral isotopes/ tracers in nutritional studies.

Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

Learning Outcome

After successful completion of this course, the students will be able to

- Appreciate the scientific knowledge in the process of various physiological functions of human body
- Utilize the methods and tools for the management of hypo/hyper metabolic stage
- Utilize knowledge for scientific deliberations
- Act as Clinical Nutritionist in medical setups
- Expert Member of Health Care Team (HCT)
- Researcher in related R&D Projects

Suggested Reading

- FAO/WHO. 2004. *Vitamins and Minerals in Human Nutrition. A report of joint FAO/WHO Expert Consultation.* 2nd Edition, World Health Organization and Food and Agriculture Organization of the United Nations.
- Garland CF, Garland FC, Gorham ED, Lipkin M, Newmark H, Mohr SB and Holick MF. 2006. *The Role of Vitamin D in Cancer Prevention*. *American Journal of Public Health*. 96(2), 252–261.
- Groff JL and Gropper S. 2012. *Advanced Nutrition and Human Metabolism*. 7th Edition, Yolanda Cossio, New York.
- Guardia M and Garrigues S. 2015. *Hand Book of Mineral Elements in Foods*. John Wiley & Sons Inc. Hoboken, New Jersey.
- Rizvi S, Raza, ST, Ahmed F, Ahmad A, Abbas S and Mahdi F. 2014. *The Role of Vitamin E in Human Health and Some Diseases*. *Sultan Qaboos University Medical Journal*, 14(2), 157–165.
- Schwalfenberg GK. 2017. *Vitamins K1 and K2: the emerging group of vitamins required for human health*. *Journal of Nutrition and Metabolism.* https://doi.org/10.1155/2017/6254836.
- https://www.who.int
- https://nutrition.org
- https://www.gainhealth.org

Weekly Lecture Schedule

Duration (week)	Topic
1	History, chemistry, distribution and functions of vitamins

2	Absorption, transport, metabolism of vitamins
3	Nutritional requirements of vitamins
4	Deficiency and manifestations of water soluble and fat soluble vitamins
5	Causes of vitamin deficiencies in India. Hypervitaminosis of water-soluble and fat-soluble vitamins
6	Vitamin fortification and supplementation
7	Methods of assay of vitamins. Interaction with other nutrients, antagonists and analogues of vitamins. Assessments of vitamin status of population
8	Causes of macro and micro mineral deficiencies in India. Chronology, chemistry and distribution of minerals
9	Deficiency manifestations of minerals. Nutritional requirements of minerals
10	Methods of assay of minerals. Interactions of minerals with other nutrients, antagonists and analogues of minerals
11	Assessment of mineral status of population. Mineral fortification and supplementation
12	Metaloenzymes. Harmful effects of major mineral pollutants on health – mutagencity, carcinogenicity. Heavy metal toxicity
13	Heavy metal toxicity
14	Antioxidants and their relationship with ageing and cancer. Antioxidants and their relationship with various non – communicable diseases. Trace minerals - their chronology, chemistry, distribution and functions. Absorption and metabolism of trace minerals
15	Functions and Requirements of trace minerals. Absorption and metabolism of trace minerals
16	Deficiency manifestation and interaction of trace minerals. Use of mineral isotopes/ tracers in nutritional studies

Course Code : **FN 603**
Course Title : **Nutrition and Agricultural Interface**
Credit Hours : **3(3+0)**

Rationale

There is a clear potential for the agriculture sector to play a critical role in enhancing food and nutrition security and health of population. Agriculture and nutrition are closely linked. Producing foods that are acceptable, accessible and affordable can make population healthy and productive, thus making a virtuous cycle. If this cycle becomes vicious, the turn-over will become negative. This course will enable the students to keep tract with agriculture scenario of a place and connect with the health status to identify, evaluate and find ways to establish positive interfaces.

Aim of the course

- To give a clear understanding of interlinking agricultural production and nutritional status of the population
- To assist the students to identify and evaluate the agriculture in terms of nutrition nexus and its effective management.

Theory

Unit I: Food production and consumption

Food situation in India and in the world; Food production and consumption trends; Food balance sheets; Role of nutrition in agricultural planning and national development.

Unit II: Food distribution

Linkages between agricultural practices and food production, distribution and nutritional status; Factors affecting food distribution at macro and micro level; Per capita food availability and consumption; Food and Nutrition security at national and household level; Role of agriculture in enhancing food security; Food crop failure and malnutrition.

Unit III: Farming systems

Poverty and vicious cycle of low food production; Effect of food production and economic policies on food availability; Impact of physical resources, farming systems, cropping system, inputs and manipulation, agricultural marketing system, post- harvest processing of foods on food and nutrition situation; Implementation of nutrition policy.

Unit IV: Agricultural programmes

Sustainable food systems, nutritional impact of agricultural programmes, food price control and consumer subsidy; Contribution of National and International organization in agricultural development.

Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

Learning Outcome

After successful completion of this course, the students will be able to

- Understand linkage between agriculture and nutrition
- Apply the knowledge in planning and implementation of agriculture and nutrition related policies
- Act as expert in developmental programmed of GOs and NGOs

Suggested Reading

- FAO. 2017. *The State of Food and Agriculture - Leveraging Food Systems for Inclusive Rural Transformation.* Food and Agriculture Organization, Rome.
- FAO. 2017. *The State of Food Security and Nutrition in the World.* Food and Agriculture Organization, Rome.
- GOI. 2016. *Agricultural Statistics at a Glance.* Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation and Farmers Welfare Directorate of Economics and Statistics, Government of India.
- GOI. 2017. *Agriculture - Statistical Year Book India*. Ministry of Statistics and Programme Implementation, Government of India.
- GOI. 2011. *Census of India*. Government of India.
- GOI. 2018. *A Reference Manualby Publication Division.* Ministry of Information about Broadcasting, Govt. of India.
- https://www.who.int
- http://www.fao.org/home/en
- https://www.india.gov.in/ agriculture
- https://mhrd.gov.in/mid-day-meal

Weekly Lecture Schedule

Duration (week)	Topic
1	Food situation in India and in the world
2	Food production and consumption trends. Food balance sheets
3	Role of nutrition in agricultural planning and national development
4	Linkages between agricultural practices and food production, distribution and nutritional status
5	Factors affecting food distribution at macro and micro level. Per capita food availability and consumption
6	Per capita food availability and consumption
7	Food and Nutrition security at national and household level
8	Role of agriculture in enhancing food security. Food crop failure and malnutrition
9	Poverty and vicious cycle of low food production. Effect of food production and economic policies on food availability
10	Impact of physical resources, farming systems, cropping system and inputs and manipulation on food and nutrition situation
11	Impact of agricultural marketing system, post-harvest processing of foods on food and nutrition situation
12	Nutrition policy implementation
13	Sustainable food systems
14	Nutritional impact of agricultural programmes
15	Food price control and consumer subsidy
16	Contribution of National and International organization for agricultural development

Course Code : FN 604
Course Title : Global Nutritional Problems
Credit Hours : 2(2+0)

Rationale

Global Nutrition Report of 2018 by WHO states that malnutrition is still rampant affecting most of world's population at some point in their life cycle from infancy to old age. No country is untouched. Malnutrition is a universal issue holding back development with unacceptable human consequences. Yet the opportunity to end malnutrition has never been better. Malnutrition is responsible for more ill-health than any other cause. It deems necessary for the students to equip thems with the knowledge of the nutrition related global problems and prepare thems with skills to address the challenges effectively.

Aim of the course

- To make the students knowledgeable about the world scenario of prevailing malnutrition in variegated forms and measures being adopted at international/ national levels
- To give opportunity to the students to identify, analyse and suggest coping strategies at global, national, regional and community levels.

Theory

Unit I: Food consumption

Food consumption pattern of underdeveloped, developing and developed countries.

Unit II: Nutritional deficiency diseases

An overview of world nutrition situation and assessment of problems of developing and developed countries in light of prevalence, aetiology, indicators and preventive measures.

Unit III: Health programmes

Nutrition and health programmes to alleviate malnutrition, role of national and international organizations.

Unit IV: Health care polices

Impact of health care polices and delivery systems; Micronutrients, food fortification and supplementation.

Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group work/ group discussion

Learning Outcome

A successful scholar with this knowledge will be able to

- Appreciate the scientific foundation of risk management associated with malnutrition and relate the key learning to the job of a professional
- Utilize methods and tools to assess the nutritional scenario and plan out suitable interventions

Suggested Reading

- Babu SC, Gajanan SN and Hallam JA. 2017. *Nutrition Economics-Principles and Policy Applications*. Science Direct. Elsevier.
- FAO. 2017. *Regional Overview of Food Security and Nutrition in Asia and the Pacific*. Food and Agriculture Organization, Rome.
- Park JE and Park K. 2007. *Text Book of Preventive and Social Medicine.* Barnasi Das Bhanot Publishers, Jabalpur.
- Semba RD and Bloem MW. 2008. *Nutrition and Health in Developing Countries*. 2nd Edition. Humana Press Inc. New York.
- Temple NJ and Steyn N. 2016. *Community Nutrition for Developing Countries*. AU Press, Athabasca University, Canada and UNISA Press, University of South Africa.
- https://www.who.int
- http://www.fao.org/home/en
- https://www.harvestplus.org
- https://www.hsph.harvard.edu/nutritionsource

Weekly Lecture Schedule

Duration (week)	Topic
1	An overview of world nutrition situation
2	Overview of global nutritional problems
3	Global nutrition intervention programmes
4	Food consumption pattern of underdeveloped countries
5	Food consumption pattern of developing countries
6	Food consumption pattern of developed countries
7	Prevalence and etiology of nutritional problems of developing countries
8	Indicators of nutritional problems of developing countries
9	Preventive measures of nutritional problems of developing countries
10	Prevalence and etiology of nutritional problems of developed countries
11	Indicators and preventive measures of nutritional problems of developed countries
12	Nutrition and health programmes to alleviate malnutrition
13	Role of national organizations in combating nutritional problems
14	Role of international organizations in combating nutritional problems
15	Impact of health care polices and delivery systems
16	Micronutrients food fortification and supplementation

Course Code : FN 605
Course Title : Nutrition in Calamities
Credit Hours : 2(2+0)

Rationale

Calamities, natural, viz., flood, earthquake, draught) or man-made, viz., riots, war, wrong policies always affect nutritional status of population which may be short-termed or long-termed depending upon the severity of the disaster. A knowledge on the topic will enable the students to act favourably for the favours of the victims to lessen the miseries in terms of health and nutrition.

Aim of the course

- To give theoretical base to the scholars in the management of food and nutritional security during a disaster. This course will cover areas of food and water supply, precautions against food shortage, adequate feeding especially of vulnerable groups, control of communicable diseases, health and hygiene, etc. during a calamity
- To equip the students with the knowledge of providing effective support systems according to the need of calamity.

Theory

Unit I: Calamities and undernutrition

Starvation in emergencies arising out of drought, floods, earth quakes, locust, war, wrong policies and poverty and climatic changes, conflict and global economic volatility, historical perspectives.

Unit II: Food needs during emergencies

Effect of inanition, short, medium and long- term emergencies on food and nutrient intake, precautions against food shortage; Population groups most vulnerable to under nutrition; Food needs at national level during normal emergencies.

Unit III: Nutritional deficiency diseases

Major nutritional deficiency diseases in emergencies, mobilization of local resources, general fund distribution, mass and supplementary feeding, therapeutic feeding, social funds; Nutritional Indices and reference standards; Preventing and handling donations in emergencies.

Unit IV: Hygiene and sanitation

Control of communicable diseases, public health and hygiene problems during emergencies.

Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

Learning Outcome

After successful completion of the course, the students will be able to:

- Assist in preparedness and disaster risk management
- Assist in taking care of vulnerable population
- Assist in nutrition risk assessment as extension professional

Suggested Reading

- FAO. 2018. *Climate Change Challenge Badge.* 2nd edition. Food and Agriculture Organization of United Nations, Rome.
- Gibney MJ. 2004. *Public Health Nutrition*. Blackwell Science, Oxford.
- Park K. 2007. *Text book of preventive and Social Medicine* 19th Edition. Banarsidas Bhanot Publishers, Jabalpur, India.
- Spark A. 2007. *Nutrition in Public Health: Principles, Policies and Practice*. CRC Press,

New York.

- WHO. 2000. *The Management of Nutrition in Major Emergencies.* World Health Organization, Geneva.
- https://www.who.int
- http://www.fao.org/home/en
- https://ndma.gov.in

Weekly Lecture Schedule

Duration (week)	Topic
1	Latest advances in management of food and nutrition in emergent situation
2	Starvation in emergencies- historical perspectives
3	Starvation in emergencies arising out of war, wrong policies, poverty and climatic changes
4	Starvation in emergencies arising out of conflict and global economic volatility
5	Starvation in emergencies arising out of drought, floods, earthquakes and locust
6	Population groups most vulnerable to under nutrition
7	Food needs at national level during normal emergencies
8	Effect of inanition, short, medium and long- term emergencies on food and nutrients intake
9	Effect of inanition, short, medium and long- term emergencies on food and nutrients intake
10	Major nutritional deficiency diseases in emergencies
11	Mobilization of local resources, general fund distribution, social funds
12	Mass and supplementary feeding programmes during emergencies
13	Therapeutic feeding programmes during emergencies
14	Nutritional Indices and reference standards
15	Communicable diseases and their control during emergencies
16	Public health and hygiene problems during emergencies

Course Code : **FN 606**
Course Title : **Maternal and Child Nutrition**
Credit Hours : **2(2+0)**

Rationale

Inadequate maternal and child nutrition is the underlying cause of considerable deaths in the third world countries. The one who survives does not grow to its full potential, remains unproductive and a burden to the society. As professionals, the students need to develop skills to provide support to this most vulnerable mother- child duo conducive to development of quality human resource.

Aim of the course

- To impart in-depth knowledge about why this vulnerable group needs special attention in terms of nutrition and other health care areas. This course will emphasize topics like nutritional challenges, physiological changes, IYCF guidelines, feeding of children with special needs, interventions, etc.
- To make students knowledgeable to identify risks and stratify coping strategies.

Theory

Unit I: Nutrition and reproduction

Nutrition challenges, physiological changes, teenage pregnancy and gestational diabetes, nutrient needs, factors affecting nutrition of the women and children.

Unit II: Nutritional deficiencies

Needs and problems of lactating women, fetal malnutrition and low birth weight, nutrition and parasites, children with special needs, Protein energy malnutrition, vitamin A, iron, vitamin D, calcium and other common deficiencies, significance of stem cell and cord blood.

Unit III: Feeding practices

Formula feeding and supplements, lactation and breast feeding in the community, HIV and breast feeding; drug abuse and breast feeding. Human milk banks, IYCF guidelines, WHO breast feeding recommendations

Unit IV: Overnutrition and undernutrition

International programs regarding child and maternal health initiative to prevent overnutrition and undernutrition.

Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Group Work/ Group Discussion

Learning Outcome

Successful completion of this course will enable the students to:

- Appreciate the scientific knowledge and relate them to actual work situation to evade long term health crisis of the concerned
- Utilize the methods and tools to assess nutritional demands and suggest coping strategies
- Utilize the knowledge for scientific publication/ population education.
- Act as scientist in related R&D projects

Suggested Reading

- Brown JE. 2016. *Nutrition through the Life Cycle*. 6th Edition. Cengage Learning, Boston.
- Ehiri J. 2009. *Maternal and Child Health - Global Challenges, Programs and Policies.* Springer Nature, Switzerland.
- Gluckman P, Hanson M, Seng CY and Bardsley A. 2015. *Nutrition and Lifestyle for Pregnancy and Breastfeeding*. Oxford University Press, UK.
- Morgan JB and Dickeson JWT. 2003. *Nutrition in Early Life*. John Wiley and Sons Ltd. Chichester.
- https://www.unicef.org
- https://www.india.gov.in/ agriculture
- https://mhrd.gov.in/mid-day-meal

Weekly Lecture Schedule

Duration (week)	Topic
1	Nutrition and reproduction
2	Nutrition challenges, physiological changes
3	Teenage pregnancy and gestational diabetes
4	Nutrient needs, factors affecting nutrition of the women and children
5	Needs and problems of lactating women
6	Foetal malnutrition and low birth weight
7	Nutrition and parasites

8	Children with special needs
9	Protein energy malnutrition, vitamin A, iron, vitamin D, calcium and other common
10	Significance of stem cell and cord blood
11	Formula feeding and supplements
12	Lactation and breast feeding in the community
13	HIV and breast feeding; drug abuse and breast feeding
14	Human milk banks, IYCF guidelines
15	WHO breast feeding recommendations
16	International programs regarding child and maternal health initiative to prevent over weight human nutrition

Course Code : FN 607
Course Title : Hormones and Enzymes
Credit Hours : 2(2+0)

Rationale

Hormones are chemical messengers providing signals to the cells for performing various functions while enzymes as catalysts enhance the rate of reaction in the body. There are few chances of occurring disease due to enzyme dysfunction however, hormonal dysfunction may give rise to lifelong diseases. Both are important biochemical materials for all living beings. Knowledge on the topic will help the students in ascertaining an effective diet counselling to address health problems linked with hormones and enzymes.

Aim of the course

- To learn in detail about the role of hormones and enzymes in human physiology and relate this information to the context of normal health and diseased state like diabetes, hypertension, renal and gastro intestinal disorders, etc. and suggesting relevant dietary managements
- To equip the students with relevant knowledge of effective dietary management of a given disease condition due to hormonal and enzymatic imbalance.

Theory

Unit I: Hormones

History, chemistry, endocrine and exocrine secretion of hormones, organs of secretion, metabolism, mechanism of action, regulation and sites of action, biological effects and interaction.

Unit II: Enzymes

Enzyme pathways in normal functions of the heart, pancreas, gastrointestinal and hepatic functions and kidneys.

Unit III: Metabolic disorders

Altered hormone and enzymatic pathways in obesity, reproductive functions, renal disorders, gastrointestinal disorders.

Unit IV: Degenerative diseases

Altered hormone and enzymatic pathways in hypertension, cardiovascular diseases, diabetes and cancer.

Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation

- Online group work/ group discussion

Learning Outcome

After successful completion of this course, a scholar will be able to:

- Utilize the scientific foundation to act as an expert of Health Care Team in medical set-ups
- Act as Clinical Nutritionists
- Act as expert in related R&D projects

Suggested Reading

- Berg JM. 2007. *Biochemistry*. 6th Edition. W. H. Freeman and Company, New York.
- Henry HL and Norman AW. 2014. *Hormones.* 3rd Edition. Academic Press, Cambridge.
- Kleine B and Rossmanith WG. 2016. *Hormones and the Endocrine System*. Springer Nature, Switzerland.
- Palmer T and Bonner PL. 2007. *Enzymes*. 2nd Edition. Woodhead Publishing, Cambridge.
- Nelson DL and Cox MM. 2017. *Lehninger Principles of Biochemistry*. 7th Edition. W.H. Freeman Company, New York.
- https://www.nutrition.org.uk
- http://www.nutritioncare.org
- https://nutrition.org

Weekly Lecture Schedule

Duration (week)	Topic
1	Histor and chemistry of hormones
2	Endocrine and exocrine secretion of hormones, organs of secretion
3	Metabolism, mechanism of action, regulation and sites of action of hormones
4	Biological effects and interaction of hormones
5	Enzyme pathways in normal functions of the heart and pancreas
6	Enzyme pathways in normal functions of the gastrointestinal and hepatic functions
7	Enzyme pathways in normal functions of the kidneys
8	Altered hormone and enzymatic pathways in diseases-hypertension
9	Altered hormone and enzymatic pathways in cardiovascular diseases
10	Altered hormone and enzymatic pathways in diabetes
11	Altered hormone and enzymatic pathways in obesity
12	Altered hormone and enzymatic pathways in metabolic disorders
13	Altered hormone and enzymatic pathways in reproductive functions
14	Altered hormone and enzymatic pathways in renal disorders
15	Altered hormone and enzymatic pathways in gastrointestinal diseases

Course Code : **FN 608**
Course Title : **Energy Metabolism**
Credit Hours : **2(2+0)**

Rationale

Energy metabolism is complex process of deriving energy from the nutrients. Imbalance in energy metabolism may be devastating for human health. It is important to understand bioenergetics to overcome the issued related to these imbalances. The understanding of the role of energy metabolism in regulation of hunger to manage body weight and other non-communicable disease by the students will help them to manage obesity related diseases.

Aim of the course

- To impart in depth knowledge to the students with new developments in the area of energy metabolism and its relation to human health
- To learn the concept of bioenergetics, thermogenesis, metabolic regulation and hunger for its application in preventing adiposity.

Theory

Unit I: Bioenergetics

Scope and application of bioenergetics for human nutrition; Energy stores in man; Components of energy; Basal metabolism, energy cost of various activities; Factors affecting energy expenditure.

Unit II: Energy expenditure

Direct and indirect methods of assessing energy expenditure; Factors affecting energy requirements; Assessment of energy requirements.

Unit III: Regulation of metabolism

Thermogenesis, metabolic regulation; Weight control and obesity-role of adipose tissues; Effect of hormones on energy metabolism.

Unit IV: Hunger

Mechanism of hunger; Psychological and physiological factors associated with adiposity.

Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

Learning Outcome

Successful completion of this course will enable the students to:

- Apply the knowledge of bioenergetics in weight management
- Use methods and tools of measuring energy expenditure
- Correlate eating behaviours of people for planning appropriate meals/diets to prevent adiposity

Suggested Reading

- Donohoue PA. 2010. *Energy Metabolism and Obesity*. Humana Press Inc. New York.
- Driskell JA and Wolinsky I. 2007. *Sports Nutrition: Energy Metabolism and Exercise*. 2nd Edition. CRC Press, New York.

- Korbonits M. 2008. *Obesity and Metabolism*. Karger Publishers, London.
- Rathore AK. 2015. *Bioenergetics, Physiology and Biostatistics*. Discovery Publishing House, New Delhi.
- Scott B. 2008. *A Primer for the Exercise and Nutrition Sciences*: *Thermodynamics,Bioenergetics, Metabolism.* Humana Press Inc. New York.
- http://www.nutritionlink.org
- https://www.icmr.nic.in
- http://www.nin.res.in

Weekly Lecture Schedule

Duration (week)	Topic
1	Scope and application of bioenergetics for human nutrition
2	Energy stores in man. Components of energy
3	Basal metabolism
4	Energy cost of various activities
5	Factors affecting energy expenditure
6	Direct methods of assessing energy expenditure
7	Indirect methods of assessing energy expenditure
8	Factors affecting energy requirements
9	Assessment of energy requirements
10	Thermogenesic
11	Metabolic regulation
12	Weight control
13	Role of adipose tissues in obesity
14	Effect of hormones on energy metabolism
15	Mechanism of hunger
16	Psychological and physiological factors associated with adiposity

Course Code : **FN 609**
Course Title : **Application of Biotechnology in Food Science and Nutrition**
Credit Hours : **3 (3+0)**

Rationale

The role of food biotechnology is important in product development. Knowledge of biotechnology will help to develop foods with enhanced taste, shelf life, nutrition and quality. Novel food products with desirable characteristics that are safe, nutritious and suitable in different physiological conditions can be developed by the application of biotechnology. Biotechnology can be an important area of application to manage hunger from population.

Aim of the course

- To understand the role of food biotechnology in quality food production for mass feeding
- To equip the students with knowledge of application of biotechnology in the process of food product development.

Theory

Unit I: Food science and biotechnology

History, processes and products of biotechnology, application of biotechnology in production of nutritious foods.

Unit II: Product development

Role of biotechnology in enzymology and product development, fermentation process, fruit juice extraction, genetic improvement of food grade microorganisms.

Unit III: Nutraceuticals

Nutritional significance of food products developed by biotechnological techniques.

Unit IV: Constraints in food biotechnology

Scientific, technological and resource constraints in biotechnology; important factors affecting development in biotechnology.

Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

Learning Outcome

Successful completion of this course will enable the students to:

- Utilize the knowledge in modifying foods for therapeutic purpose
- Serve as investigative dietitian in developing novel food products in food industry

Suggested Reading

- Nestle M. 2003. *Safe Food: Bacteria, Biotechnology and Bioterrorism*. University of California Press Ltd., London.
- Panesar PS and Marwaha. 2014. *Biotechnology in Agriculture and Food Processing: Opportunities and Challenges.* CRC Press, Boca Raton, Florida.
- Shetty K, Paliyath G, Pometto A and Levin RE. 2011. *Food Biotechnology*. 2nd Edition, CRC Press, New York.
- Ravishankar Rai V. 2015. *Advances in Food Biotechnology*. Wiley-Blackwell Publishing Company, Boston.
- https://www.bio.org

Weekly Lecture Schedule

Duration (week)	Topic
1	History of biotechnology
2	Processes and products of biotechnology
4	Application of biotechnology in production of nutritious foods
6	Role of biotechnology in enzymology
7	Product development
8	Fermentation process
9	Fruit juice extraction
10	Genetic improvement of food grade microorganisms
12	Nutritional significance of food products developed by biotechnological techniques
14	Resource constraints on biotechnology
15	Technological constraints on biotechnology

Course Code : **FN 610**
Course Title : **Recent Trends in Food Science and Technology**
Credit Hours : **3(3+0)**

Rationale

Environment and food can influence individual's health due to interaction between genes and food components that can cast positive or negative impact on human health. Nutrigenomics relates human genome with response of body to the food. In depth study of recent advances in the field of food analysis and food fortification is imperative to reduce double burden of malnutrition. With the use of application of food science and technology, the novel foods can be formulated which are safe, wholesome and nutritious.

Aim of the course

- To acquaint the students with latest advances in food science and technology to meet nutritional challenges
- To understand the integration of genomic science with nutrition
- To understand the physical, chemical and biological makeup of food and ways of food processing and packaging.

Theory

Unit I: Macro and micronutrients

Recent advances in the field of carbohydrates, lipids, proteins, vitamins and minerals in relation to food science; Nutrigenomics, incorporating genetics into dietary guidance.

Unit II: Food analysis

Recent advances in the field of food analysis and food fortification.

Unit III: Advanced techniques

Membrane technology: micro-filtration, ultra-filtration, nano-filtration, reverse osmosis and their applications in food industry; Supercritical fluid extraction-concept and extraction methods; Microwave and radio frequency processing-mechanism and application in food processing; Hurdle technology- concept and its applications.

Unit IV: Foods of future

Food processing and product development; regulating; food processing and preservation through Total Quality Management (TQM) and Hazard Analysis and Critical Control Points (HACCP); Genetically Modified Foods (GM) foods and their health implications, functional foods and organic foods.

Teaching Methods/Activities

- Lectures
- Assignment (Writing/Reading)
- Students' presentation
- Online Group Discussion

Learning Outcome

Successful completion of this course will enable the students to:

- Understand the recent advances in technologies used in food industry
- Gain in knowledge of genetically modified, safe and nutritious food products to maintain and improve human health

- Serve as novel therapeutic food designer in pharmaceutical/nutraceutical companies

Suggested Reading

- Clark S, Jung S and Lamsal B. 2014. *Food Processing - Principles and Applications*. 2nd Edition, Wiley-Blackwell Publishing Company, Boston.
- deMan JM, Finley JW, Hurst WJ and Lee CY. 2018. *Principles of Food Chemistry*. 4th Edition, Springer International Publishing, New York.
- Fellows PJ. 2017. *Food Processing Technology*. 4th Edition, Woodhead Publishing Ltd. Cambridge.
- Hartel RW and Heldman D. 2012. *Principles of Food Processing*. Aspen Publishers Inc. New York.
- Ward JD and Ward LT. 2012. *Principles of Food Science*. Goodheart-Willcox Publisher, Illinois.
- https://www.gainhealth.org
- https://foodprocessingindia.co.in
- http://agronfoodprocessing.com

Weekly Lecture Schedule

Duration (week)	Topic
1	Recent advances in the field of carbohydrates, lipids and proteins in relation to human nutrition
2	Recent advances in the field of vitamins and minerals in relation to human nutrition
3	Nutrigenomics
4	Incorporating genetics into dietary guidance
5	Recent advances in the field of food analysis
6	Recent advances in the field of food fortification
7	Membrane technology: micro-filtration, ultra-filtration
8	Reverse osmosis and their applications in food industry
9	Supercritical fluid extraction- concept and extraction methods
10	Microwave and radio frequency processing- mechanism and application in food processing
11	Hurdle technology- concept and its applications
12	Foods of future; special nutrients
13	Food processing and product development
14	Regulating food processing and preservation through Total Quality Management (TQM)
15	Hazard Analysis and Critical Control Points (HACCP)
16	Genetically Modified Foods (GM) foods and their health implications, functional foods and organic foods

MINOR COURSES

Course Code **:FN 515**
Course Title **: Food Science and Technology**
Credit Hours **: 3(2+1)**

Rationale

The aim of this course is to enable the students to acquire the scientific, technical and professional skills for a career in the food industry/food research and teaching institutions through an understanding of food science and technology.

Aim of the course

To acquaint the students with latest advances in Food Science and Technology upon which more advanced and specialized knowledge can be built.

Theory

Unit I: Food for us

Food: Classification of foods, Health foods, Natural foods, Organic food, Functional food, Nutraceuticals, Nutrigenomics, Specialty Foods, Fast Foods, space foods, food fortification, restoration and enrichment, anti-nutritional factors, GM food and its safety concern. Food processing and preservation through Total Quality Management (TQM) and Hazard Analysis and Critical Control Point (HACCP)

Unit II: Sensory evaluation of foods

Introduction - Subjective evaluation, sensory evaluation: definition, and applications and sensory attributes of food: Appearance, texture and flavor; difference between objective and subjective evaluation. Sensory measurements- Kinds of sensory tests- difference:- triangle, duo-trio tests, paired comparison tests, descriptive tests:- texture profile, flavor, profile, affective tests:- preference test, ranking test, hedonic tests. Factors affecting sensory measurements:- psychological – expectation error, mutual suggestion effect, distraction error etc; physiological : adaptation, mixture interactions-enhancement, synergy,& suppression, health and environmental factors.

Unit III: Emerging trends in minimal processing of foods

High Hydrostatic Pressure Technology, Oscillating Magnetic Field, High intensity pulsed electric field, Pulse Light Technology, Ultraviolet light technology, Ultra sound technology, Applications of ozone in fruit processing, Electrolysed water treatment, edible coatings, multilayer coatings, osmotic membrane coatings, Enzyme maceration

Unit IV: Potential Food Preservation Methods Irradiation Preservation in Foods:

Food irradiation process, dose and dosimetry, scope of irradiation, special advantages of irradiation, effect of food irradiation on micro organisms and food components and application of irradiation in foods of plant origin and animal origin. Preserving food with Electricity (Ohmic heating): Definition, heat generation, effect of ohmic heating on foods and food components, applications in food industry. Microwave heating: Principles, Unit of microwave, advantages and disadvantages of microwave, applications of microwave in food industry. Combined Methods for Food Preservation: Introduction, Principles of Combined preservation methods (Hurdle effect, hurdle technology, total quality, potential hurdles), application of hurdle technology.

Practicals

- Product development and shelf life studies of nutritionally fortified foods
- Learning different sensory evaluation techniques in food
- Visit to food industries to see and understand latest technologies in food industry

Teaching Methods/Activities

- Lectures
- Assignment (writing/reading)
- Students' presentation
- Group activities
- Hands on training

Learning outcome

The student will be able to understand the recent technological advances in food industry and able to apply different aspects in their career.

Suggested Reading

- Frederick, J.F, 2000, Encyclopedia of Food Science and Technology. Second edition vol 1-4, a widely inter science publication.
- Goldberg, I., 1999 Functional foods, Designer foods, pharma foods and nutraceuticals. An aspen publication, gaithers burg, Maryland.
- Roday, S., 2008, Food science and nutrition. Third edition, Oxford University Press, New Delhi.
- Khader, V, 2001, Text book of Food science and Technology. Published by India Council of Agricultural Research, New Delhi 110012.
- Manay, N.S,2004, Shadaksharaswamy, M., Foods- Facts and Principles, New Age International Publishers, New Delhi.
- Srilakshmi, B, 2003, Food Science (3rd edition), New Age International (P) Limited Publishers, New Delhi.
- Reddy Y.S, 2006, Newer concept and applications for food industry. Gene tech Books, New Delhi 110002.
- Harry T Lawless, Hildegarde Heymann (2010) Sensory evaluation of Food: Principles and Practices, Second Edition, Springer, New York.
- Sarah Kemp, Tracey Hollywood, Joanne Hort (2011) Sensory evaluation: A Practical Hand- book, Wiley-Blackwell, New York.
- Nielsen, S.S, 2004 Introduction to the chemical analysis of foods. Jones and Bartlett Publishers, Boston, London.

Weekly Lecture Schedule

Duration (week)	Topic
1	Classification of foods, Health foods, Natural foods, Organic food, Functional food, Nutraceuticals
2	Nutrigenomics, specialty foods, fast foods, space foods
3	Food fortification, restoration and enrichment, anti-nutritional factors present in foods
4	GM food and its safety concern
5	Food processing and preservation through Total Quality Management (TQM) and Hazard Analysis and Critical Control Point (HACCP)
6	Introduction - Subjective evaluation, sensory evaluation: definition, and applications and sensory attributes of food: Appearance, texture and flavor; difference between objective

	and subjective evaluation
7	Sensory measurements- Kinds of sensory tests- difference:- triangle, duo-trio tests, paired comparison tests, descriptive tests:- texture profile, flavor, profile, affective tests:- preference test, ranking test, hedonic tests
8	Factors affecting sensory measurements - psychological – expectation error, mutual suggestion effect, distraction error etc.
9	Physiological: adaptation, mixture interactions-enhancement, synergy & suppression, health and environmental factors
10	Emerging trends in minimal processing of foods - High Hydrostatic Pressure Technology, Oscillating Magnetic Field, High intensity pulsed electric field
11	Pulse Light Technology, Ultraviolet light technology, Ultra sound technology
12	Applications of ozone in fruit processing, Electrolyzed water treatment, edible coatings, multilayer coatings, osmotic membrane coatings, Enzyme maceration
13	Potential Food Preservation Methods Irradiation Preservation in Foods: Food irradiation process, dose and dosimetry, scope of irradiation, special advantages of irradiation, effect of food irradiation on micro organisms and food components and application of irradiation in foods of plant origin and animal origin
14	Preserving food with Electricity (Ohmic heating): Definition, heat generation, effect of ohmic heating on foods and food components, applications in food industry
15	Microwave heating: Principles, Unit of microwave, advantages and disadvantages of microwave, applications of microwave in food industry
16	Combined Methods for Food Preservation: Introduction, Principles of Combined preservation methods (Hurdle effect, hurdle technology, total quality, potential hurdles), application of hurdle technology

Course Code **:FN 516**
Course Title **: Food Biochemistry**
Credit Hours **: 3(2+1)**

Rationale

Food safety, security and quality assurance have today become subject of national importance. Food safety, security and quality assurance have today become subject of national importance. Food Biochemistry attempts to emphasize the importance of biochemistry in the rapidly developing field of food science, and to provide a deeper understanding of those chemical changes occurring in foods.

Aim of the course

- To understand the chemistry of foods - composition of food, role of each component and their interaction.
- To understand the functional aspects of food components and to study their role in food processing in biochemical process.

- To understand the chemistry of food components and their interactions.

Theory

Unit-I Introduction

- Definition, Composition of food ,Development of food chemistry and its in role food processing.
- Water: Importance of water in foods. Structure of water & ice. Concept of bound & free water and their implications. Properties of water, weak acids & weak bass, pH & buffers.
- Carbohydrates: Nomenclature and classification, structure, physical and chemical properties of carbohydrates – monosaccharide, disaccharides and polysaccharides (cellulose, starch, fructans, galactans, hemi-cellulose, pectic substances) and their functions; dietary fiber, changes in carbohydrates during processing.

Unit II: Proteins:

- Nomenclature, classification, structure, chemistry and properties of amino acids, peptides, proteins. essential and non- essential amino acids. Changes during processing.

Unit III Lipids:

- Structure, classification, physical and chemical properties of fatty acids and glycerides, Auto-oxidation, photo oxidation and flavor reversion, Changes in fats & oils during processing. Vitamins & Minerals: Types, chemistry and functions, source and deficiency diseases. Changes during processing.

Unit IV Enzymes:

- Nomenclature, mechanism of enzyme action, factors affecting enzyme action, enzymes important in foods. Pigments: Structure and properties of chlorophyll, anthocyanins, tannin, myoglobin and carotenoids, chemical changes during processing.

Related experiences

Visit to a lab to observe the various techniques in food biochemistry

Practicals

- Preparation of primary and secondary solutions.
- Estimation of moisture content.
- Determination of gelatinization temperature range (GTR) of different starches and effect of additives on GTR.
- Determination of refractive index and specific gravity of fats and oils.
- Determination of smoke point and percent fat absorption for different fat and oils.
- Determination of percent free fatty acids.
- Estimation of saponification value.
- Estimation of reducing and non-reducing sugars using potassium ferricyanide method.

Teaching Methods/ Activities

a. Lectures
b. Assignment (Writing/Reading)
c. Students' presentation
d. Group activities
e. On field case studies

Learning Outcome

I. Understand the fundamental biochemical principles, structure/function of bio-molecules, metabolic pathways and the regulation of biochemical processes.

II. Understand the the mechanism of enzyme action and identify factors affecting their action.

III. Understand and be able to control the major chemical and biochemical (enzymatic) reactions that influence food quality with emphasis on food industry applications.

IV. Understand how the properties of different food components and interactions among these components modulate the specific quality attributes of food systems.

Suggested Reading

- Biology for Chemist by Agrawal & Agrawal.
- Biochemistry by Albert L Lehninger.
- Biochemistry by U Satyanarayana &U Chakrapani.
- Fundamentals of Biochemistry by J L Jain, Sunjay Jain & Nitin Jain.
- Food Chemistry by Meyer.
- Food Chemistry by Belitz.
- Food Chemistry by Lee.
- Principles of Biochemistry by Lehnniger.

Weekly Lecture Schedule

Duration (week)	Topic
1-2	Introduction to Food Chemistry Definition, Composition of food, Development of food chemistry and its in role food processing. Water -Definition of water in food, Structure of water and ice, Types of water, Sorption phenomenon, Properties of water, weak acids & weak bass, pH & buffers. Water activity and packaging, Water activity and shelf-life
3-5	Carbohydrates- Nomenclature and Classification (mono, oligo and poly saccharides) Structure of important polysaccharides(starch, glycogen, cellulose, pectin, hemicellulose, gums). , physical and chemical properties of carbohydrates – monosaccharide, disaccharides and polysaccharides (cellulose, starch, fructans, galactans, hemi-cellulose, pectic substances) and their functions; dietary fiber, changes in carbohydrates during processing. Chemical reactions of carbohydrates –oxidation, reduction, with acid & alkaki, Modified celluloses and starches.
6-8	Proteins Nomenclature, Protein classification and structure. Nature of food proteins (plant and animal proteins) Properties of proteins (electrophoresis, sedimentation, amphoterism and denaturation,) chemistry and properties of amino acids, peptides, proteins. essential and non changes during processing. Functional properties of proteins eg. organoleptic, solubility, viscosity, binding gelation / texturization, emulsification, foaming.

9-11	Lipids Structure, Classification of lipids Physical properties-melting point, softening point, specific gravity, refractive index, smoke, flash and fire point, turbidity point. Chemical properties-reichert meissel value, polenske value, iodine value, peroxide value, saponification value. Effect of frying on fats. Changes in fats and oils- rancidity, lipolysis, flavor reversion. Auto-oxidation, photo oxidation and flavor reversion, Changes in fats & oils during processing. Auto-oxidation and its prevention. Technology of edible fats and oils- Refining, Hydrogenation and Interesterification, Fat Mimetics.
12-13	Vitamins Structure, Types, chemistry and functions, Importance and Stability. Water soluble vitamins. Fat soluble vitamins. Changes during processing
14-15	Minerals Structure, Types, chemistry and functions, Major and minor minerals. Metal uptake in canned foods. Toxic metals. Changes during processing.
16	Enzymes Introduction, classification Nomenclature, mechanism of enzyme action, factors affecting enzyme action, enzymes important in foods. General characteristics. Pigments: Structure and properties of chlorophyll, anthocyanins, tannin, myoglobin and carotenoid. Enzymes in food processing. Industrial Uses of Enzymes. Immobilized enzymes. Chemical changes during processing.

Course Code **:FN 517**
Course Title **: Nutritional Biochemistry**
Credit Hours **: 3(2+1)**

Rationale

The impact of nutrition on both physical and mental health has become important and the emerging studies are finding more strong connections between diet, gut health and the microbiome, and various diseases. Research into these connections is being undertaken by the field of nutritional biochemistry which investigates the mechanisms which underly these interactions between diet and disease. Adequate knowledge about this minor course on nutritional biochemistry in totality will enable the students to handle the nutrition situations of a population and how to imply the knowledge for sustainable handling to induce better health and productivity. Therefore, the necessity lies in this minor course.

Aim of the course

To enable the students to

- Obtain depth in the study of Biochemistry of major nutrients and metabolic pathways.
- Understand the application of Biochemistry in the field of Foods and Nutrition.
- To discuss the metabolite pathways of major nutrients in the body
- To familiarise the techniques used in biochemistry.

Theory

UNIT I- Biological Membranes and Acid-Base Homeostasis

Biological Membranes - Introduction to membrane structures, Composition of membrane structures, Transport process across cell membranes. Acid-Base Homeostasis - Introduction, Acid, Base & pH, Acid base balance and its regulation in human body.

UNIT II Carbohydrate metabolism

Introduction - Cellular metabolism of carbohydrates, Glycogen metabolism, Regulation of carbohydrate metabolism at substrate level, enzyme level, hormonal level and organ level. Introduction to intermediary metabolism - Starve-feed cycle- Caloric homeostasis & futile cycles- Tricarboxylic acid cycle-Biological Oxidation- Electron transport chain- Oxidative phosphorylation.

UNIT III Proteins, Aminoacids and Nucleic acids metabolism

Metabolism of amino acids, Biosynthesis of protein, amino acids, non-protein amino acids (urea cycle, transamination, one-carbon metabolism), Creatine and creatinine, Plasma proteins – Nature, properties and functions, Biologically active peptides, polypeptides and transport proteins. Synthesis and Breakdown of Haemoglobin, Bile Pigments. Biochemical aspects of purine and pyrimidines. Biosynthesis and breakdown of purine and pyrimidine. Role of purine & pyrimidine nucleotides in metabolism. Composition, functions and classification Isolation, structure and properties of DNA and RNA (M-RNA, T-RNA and R-RNA).

UNIT IV Lipids and Enzyme metabolism

Cellular uptake & metabolism of lipids (beta-oxidation, synthesis and breakdown of unsaturated fatty acids, cholesterol, phospholipids & triacylglycerol), Lipoprotein metabolism, VLDL and LDL (‘Forward’ Cholesterol transport) VLDL and LDL (Endogenous TAG transport), HDL (‘Reverse’ Cholesterol transport), Regulation of lipid metabolism. Introduction to enzymes & its synthesis – Kinetics, Enzyme specificity-Regulation of enzyme activity- Enzymes in clinical diagnosis- Metabolism of xenobiotics, free radicals, ROS & oxidative damage.

Related experiences

Visit to a lab to observe the various techniques in biochemistry.

Practicals

- 1-3 Qualitative estimation a. Sugars and aminoacids.
- 4 Operation of equipments.
- 5-9 Analysis of Urine for a. Creatinine b. Urea c. Vitamin C, d. Calcium.
- 10-13 Blood parameters – serum protein, blood urea.
- 14-16 Estimation of RNA & DNA.

Teaching Methods/ Activities

- Lectures.

- Assignment (Writing/Reading).
- Students' presentation.
- Group activities.
- On field case studies.

Learning Outcome

Completion of the course will enable the students to:

- Understand underlying causes of diseases.
- Appreciate the scientific foundation for better management of risks factors.
- Act as confident members in healthcare teams.
- Utilize information for publication/ education.

Suggested Reading

- Harold. A. Harper, Review of Physiological Chemistry, 16th Ed. The Kothari book Depot, Bombay.
- Albert, L. Lehninger, Biochemistry 2nd Ed. The Johns Hopkins University school of Medicine, 1975.
- White, A., Andler, P. and Smith, E.L. Principle of Biochemistry, 5 th ed. Mc Graw Hill, Kogakusha.Ltd.1975.
- Henry, R, Mahler and Eugene H. Cordes, Basic Biological Chemistry, 2 nd ed., Harper International Ed., Harper and Row Publications, New York,1968.
- West, E.S. Todd, W.R. Mason, H.S and Van Burggen, J.T. Text Book of Biochemistry, IV Ed . Mac million Co., New York,1968.
- Nikola, Experimental Methods, Biophysical Methods, John Wiley & Sons, Inc.
- Sepal, Biochemical calculation, Holland Publishing Co,1970.
- Viewing Instrumental methods, chemical analysis, Mc Graw Hill Co.
- Zweig and Whitaker, Paper chromatography and Electrophoresis, Arnold Pvt ltd,1975
- Harold Varley, Practical Clinical Biochemistry, Arnold Pvt Ltd,1975.
- Paul, D. Soyer, The Enzyme ,3 rd Ed, Academic Press.
- Murray, R.K., Graner, D.K., Mayes, P.A. and Rodwell, V.W. (2000): 25th Ed. Harpers.
- Biochemistry Macmillan Worth Publishers.

Weekly Lecture Schedule

Duration (week)	Topic
1	Introduction to membrane structures & Composition of membrane structures
2	Transport process across cell membranes
3	Introduction- Acid, Base & pH, Acid base balance and its regulation in human body
4	Cellular metabolism of carbohydrates- Glycogen metabolism, Regulation of carbohydrate metabolism
5-6	Intermediary metabolism -Starve-feed cycle- Caloric homeostasis & futile cycles- TCA -Biological Oxidation- Electron transport chain- Oxidative phosphorylation
7-8	Metabolism of amino acids, Biosynthesis of protein, amino acids, non-protein amino acids (urea cycle, transamination, one-carbon metabolism)
9-10	Creatine and creatinine, Plasma proteins – Nature, properties and functions, Biologically active peptides, polypeptides and

	transport proteins. Synthesis and Breakdown of Haemoglobin, Bile Pigments
11-12	Biochemical aspects of purine and pyrimidines. Biosynthesis and breakdown of purine and pyrimidine. Composition, functions and classification Isolation, structure and properties of DNA and RNA
13-14	Cellular uptake & metabolism of lipids, Regulation of lipid metabolism
15-16	Introduction to enzymes & its synthesis - Kinetics, Enzyme specificity- Regulation of enzyme activity- Enzymes in clinical diagnosis- Enzyme detoxification in the body-Metabolism of xenobiotics, free radicals, ROS & oxidative damage

Course Code **:FN 518**
Course Title **: Food Microbiology**
Credit Hours **: 3(2+1)**

Rationale

There is need to know about the microbiological aspects involved in different settings of food industry and also an understanding of safety standards to be followed in a food industry

Aim of the course

- Identify microorganisms associated with food.
- Describe different type of microbes present and their beneficial as well as deleterious effect on food.
- Understand food borne pathogens, food spoilage and toxins produced by them and its health effect.
- Assess the importance of microbes in food industry for baking, fermentation and various traditional foods

Theory

Unit I: History and scope of food microbiology.

Types of micro-organisms associated with food- mold, yeast, and bacteria, Microbial growth pattern, physical and chemical factors influencing destruction of microorganisms. Growth curve, bacterial group based on morphology- gram positive, gram negative, motile, non-motile, sporulating and non sporulating. Microorganisms in natural food products and their control.

Unit II: Microbial intoxication and infections:

Sources of infection of food by pathogenic organisms, symptoms and method of control. Sources of contamination of food, mycotoxins, toxin production and physiological action, .

Unit III: Microbiology of different foods

a) Cereal and cereal products
b) Sugar and sugar products.
c) Vegetables and fruits
d) Meat and meat products
e) Fish, egg and poultry,
f) Milk and milk products
g) Canned foods.

Novel microbial Food Products for Human Consumption History of Single Cell Protein (SCP); Microbial SCP production by bacteria, algae and mycoprotein from fungi for use as food and feed; SCP production process by using different substrates; properties and nutritional values; Industrially used SCP (Quoron, Pruteen); Advantage and disadvantages of SCP. Mushroom cultivation, harvesting and post harvesting; important edible mushroom sp.

Unit IV: Fermentation:

Importance of microorganisms in food industry and food preparations (milk industry, meat, fish, baking). Food fermentation -Traditional fermented foods of India and other Asian countries; Probiotics and prebiotics: effect on gut microflora. Fermented foods based on milk, meat and vegetables; Fermented and alcoholic beverages. Hazard analysis criteria control points (HACCP) system for food safety, HACCP principles, Application of HACCP principles

Practical

- Microbiological apparatus
- 2-4 Culture media, Techniques of culturing
- Staining techniques
- 6-7 Identification of fungi and yeast
- 8-9 Bacterial testing
- 10-11 Microbiological testing of water
- 12-14 Analysis of food samples
- 15-16 Sampling and analysis of microbial load on food contact surfaces

Teaching Methods/Activities

- Lectures
- Assignment(writing/reading)
- Students' presentation
- Group activities
- Hands on training

Learning outcome

After completion of course,

- The student will be able to apply microbiological aspects involved in different settings of food industry
- The student can participate in formulating, implementing and evaluating Food safety measures in institutions

Learning Outcome

On completion of the course the student will be able to-

- Understand important pathogens and spoilage microorganisms in foods and methods of inactivating/preventing their action
- Learn the newer applications of microbes in Food processing

Suggested Reading

- Banwart G J., 1987, Basic Food Microbiology, CBS Publishers and Distributors
- Frazier WC, Westoff DC. 1998, Food Microbiology, 4thEdition, Tata Mc Graw Hill Publishing Co. Ltd
- Prescott L M, Harley J P, Klein D A., 2008. Microbiology 6th Ed., WMC Brown Publishers
- Pelczar MJ, Chan ECS, Krieg N. 1993. Microbiology 5th Ed., Tata McGraw Hill Publishing Co. Ltd
- Garbutt John, 1997. Essentials of Food Microbiology, Arnold London
- James M. Jay, 2000. Modern Food Microbiology 6th edition AN ASPEN

PUBLICATION® Aspen Publishers, Inc.

Weekly lecture Schedule

Duration (week)	Topic
1	History and scope of food microbiology. Types of micro-organisms associated with food- mold, yeast, and bacteria
2	Microbial growth pattern, physical and chemical factors influencing destruction of microorganisms. Growth curve
3	bacterial group based on morphology- gram positive, gram negative, motile, non-motile, sporulating and non sporulating
4	Microorganisms in natural food products and their control
5	Novelmicrobial Food Products for Human Consumption -Single Cell protein
6	Mushroom cultivation –cultivation, harvesting, importantsp
7	Sources of infection of food by pathogenic bacteria, symptoms and method of control
8	Sources of infection of food by pathogenic virus and yeast, symptoms and method of control
9	Sources of contamination of food, mycotoxins, toxin production and physiological action
10	Microbiology of Cereal and cereal products, Sugar and sugar products, Vegetables and fruits
11	Microbiology of Meat and meat products, Fish, egg and poultry, Milk and milk products& Canned foods
12	Fermentation: Importance of microorganisms in food industry and food preparations (milk industry, meat, fish, baking)
13	Food fermentation -Traditional fermented foods of India and other Asian countries
14	Probiotics and prebiotics: effect on gut microflora. Fermented foods based on milk, meat and vegetables
15	Fermented and alcoholic beverages
16	Hazard analysis criteria control points (HACCP) system for food safety, HACCP principles, Application of HACCP principles

AGRICULTURAL STATISTICS

Course Title with Credit Load for M.Sc. in Agricultural Statistics

Course Code	Course Title	Credit Hours
*STAT 552	Probability Theory	2+0
*STAT 553	Statistical Methods	2+1
*STAT 562	Statistical Inference	2+1
*STAT 563	Design of Experiments	2+1
*STAT 564	Sampling Techniques	2+1
*STAT 565	Statistical Genetics	2+1
*STAT 571	Multivariate Analysis	2+1
*STAT 572	Regression Analysis	1+1
*STAT 573	Statistical Computing	1+1
STAT 591	Seminar	0+1
STAT 599	Research	0+30
STAT 551	Mathematics-I	3+0
STAT 554	Actuarial Statistics	2+0
STAT 555	Bioinformatics	2+0
STAT 556	Econometrics	2+0
STAT 561	Mathematics-II	2+0
STAT 566	Statistical Quality Control	2+0
STAT 567	Optimization Techniques	1+1
STAT 574	Time Series Analysis	1+1
STAT 575	Demography	2+0
STAT 576	Statistical Methods for Life Sciences	2+0
STAT 577	Statistical Ecology	2+0
Supporting Courses		
STAT 501	Mathematics for Applied Sciences	2+0
STAT 502	Statistical Methods for Applied Sciences	3+1
STAT 511	Experimental Designs	2+1
STAT 512	Basic Sampling Techniques	2+1
STAT 521	Applied Regression Analysis	2+1
STAT 522	Data Analysis Using Statistical Packages	2+1
STAT 523	Applied Genetic Statistics	2+1
STAT 524	Applied Multivariate Analysis	1+1

*Core Courses

MCA 501	Computers Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Networking and Internet Applications	1+1
MCA 512	Information Technology in Agriculture	2+0

I. **Course Title** **: Mathematics for Applied Sciences**

II. **Course Code** **: STAT 501**

III. **Credit Hours** **: 2+0**

IV. **Aim of the course**

This course is meant for students who do not have sufficient background of Mathematics. The students would be exposed to elementary mathematics that would prepare them to study their main courses that involve knowledge of Mathematics. The students would get an exposure to Linear Algebra, differentiation, integration and differential equations etc.

V. **Theory**

Unit I

Set theory-set operations, finite and infinite sets, operations of set, function.

Unit II

Vectors and vector spaces, Matrices notations and operations, laws of matrix algebra; transpose and inverse of matrix, Eigen values and Eigen vectors. Determinants - evaluation and properties of determinants, Solutions of Linear Equations.

Unit III

Variables and functions, limits and continuity of specific functions. Differentiation: theorems of differentiation, differentiation of logarithmic, trigonometric, exponential and inverse functions, Differentiation of function of a function, derivatives of higher order, partial derivatives. Application of derivatives, determination of points of inflexion, maxima and minima.

Unit IV

Integration, methods of integration, reduction formulae, definite and indefinite integral, Applications of integration in Agriculture, Differential Equations.

VI. **Suggested Reading**

- Hohn FE. 2013. *Elementary Matrix Algebra*, 3rd Ed., Kindle Edition
- Harville D.A. 1997. *Matrix Algebra from a Statistician's Perspective*. Springer.
- Hohn F.E. 1973. *Elementary Matrix Algebra*. Macmillan.
- Searle S.R. 1982. *Matrix Algebra Useful for Statistics*. John Wiley. Stewart J. 2007. *Calculus*. Thompson.
- Thomas G.B. Jr. and Finney R.L. 1996. *Calculus*. 9th Ed. Pearson Edu.

I. **Course Title** **: Statistical Methods for Applied Sciences**

II. **Course Code** **: STAT 502**

III. **Credit Hours** **: 3+1**

IV. **Aim of the couse**

This course is meant for students who do not have sufficient background of Statistical Methods. The students would be exposed to concepts of statistical methods and statistical inference that would help them in understanding the importance of statistics. It would also help them in understanding the concepts involved in data presentation, analysis and interpretation. The students would get an exposure to presentation of data, probability distributions, parameter estimation, tests of significance, regression analytical techniques.

IV. Theory

Unit I

Box-plot, Descriptive statistics, Exploratory data analysis, Theory of probability, Random variable and mathematical expectation.

Unit II

Discrete and continuous probability distributions, Binomial, Poisson, Negative Binomial, Normal distribution and their applications. Concept of sampling distribution: chi-square, t and F distributions. Tests of significance based on Normal, chi-square, t and F distributions.

Unit III

Introduction to theory of estimation and confidence-intervals, Simple and multiple correlation coefficient, partial correlation, rank correlation, Simple and multiple linear regression model, test of significance of correlation coefficient and regression coefficients, Coefficient of determination, Fitting of quadratic models.

Unit IV

Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Run test for the randomness of a sequence. Median test.

Unit V

Introduction to ANOVA: One way and Two Way, Introduction to Sampling Techniques, Kruskal Wallis test and Friedman's non parametric test.

V. Practical

- Exploratory data analysis, fitting of distributions ~ Binomial, Poisson, Negative Binomial, Normal.
- Large sample tests, testing of hypothesis based on exact sampling distributions ~ chi square, t and F.
- Confidence interval estimation and Correlation and regression analysis, fitting of Linear and Quadratic Model.
- Non-parametric tests. ANOVA: One way, Two Way.
- Kruskal Wallis test and Friedman's non parametric test.

VI. Suggested Reading

- Goon A.M, Gupta M.K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A.M, Gupta M.K. and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. The World Press.
- Hoel P.G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R.V and Craig T.T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Morrison D.F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Hogg RV, McKean JW, Craig AT. 2012. *Introduction to Mathematical Statistics* 7th Edition.
- Siegel S, Johan N & Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.
- Anderson TW. 2009. *An Introduction to Multivariate Statistical Analysis*, 3rd Ed . John Wiley

- http://freestatistics.altervista.org/en/learning.php.
- http://www.statsoft.com/textbook/stathome.html.

I. Course Title : Experimental Designs

II. Course Code : STAT 511

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students of agricultural and animal sciences other than Agricultural Statistics. Designing an experiment is an integrated component of research in almost all sciences. The students would be exposed to concepts of Design of Experiments so as to enable them to understand the concepts involved in planning, designing their experiments and analysis of experimental data.

V. Theory

Unit I

Need for designing of experiments, characteristics of a good design. Basic principles of designs- randomization, replication and local control.

Unit II

Uniformity trials, size and shape of plots and blocks, Analysis of variance, Completely randomized design, randomized block design and Latin square design.

Unit III

Factorial experiments, (symmetrical as well as asymmetrical), orthogonality and partitioning of degrees of freedom. Concept of confounding.

Unit IV

Split plot and strip plot designs, analysis of covariance and missing plot techniques in randomized block and Latin square designs; Transformations, Balanced Incomplete Block Design, resolvable designs and their applications, Lattice design, alpha design - concepts, randomization procedure, analysis and interpretation of results. Response surfaces. Combined analysis. Augmented designs and its analysis.

VI. Practical

- Uniformity trial data analysis, formation of plots and blocks, Fairfield Smith Law, Analysis of data obtained from CRD, RBD, LSD, Analysis of factorial experiments,
- Analysis with missing data,
- Split plot and strip plot designs.
- combined analysis and analysis of Augmented Designs.

VII. Suggested Reading

- Cochran WG and Cox GM. 1957. *Experimental Designs*. 2nd Ed. John Wiley.
- Dean AM and Voss D. 1999. *Design and Analysis of Experiments*. Springer.
- Montgomery DC. 2012. *Design and Analysis of Experiments*, 8th Ed.

John Wiley.
- Federer WT. 1985. *Experimental Designs*. MacMillan.
- Fisher RA. 1953. *Design and Analysis of Experiments*. Oliver & Boyd.
- Nigam AK and Gupta VK. 1979. *Handbook on Analysis of Agricultural Experiments*. IASRI Publ.
- Pearce SC. 1983. *The Agricultural Field Experiment: A Statistical Examination of Theory*
- *and Practice*. John Wiley. www.drs.icar.gov.in.

I. Course Title : Basic Sampling Techniques

II. Course Code : STAT 512

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students of agricultural and animal sciences other than Statistics. The students would be exposed to elementary sampling techniques. It would help them in understanding the concepts involved in planning and designing their surveys, presentation of survey data analysis of survey data and presentation of results. This course would be especially important to the students of social sciences.

V. Theory

Unit I

Concept of sampling, sample survey vs complete enumeration, planning of sample survey, sampling from a finite population.

Unit II

Simple random sampling with and without replacement, sampling for proportion, determination of sample size, inverse sampling, Stratified sampling.

Unit III

Cluster sampling, Multi-stage sampling, systematic sampling; Introduction to PPS sampling,

Unit IV

Use of auxiliary information at estimation, Ratio product and regression estimators. Double Sampling, sampling and non-sampling errors. Non-probability sampling.

VI. Practical

- Random sampling ~ use of random number tables, concepts of unbiasedness, variance, etc.;
- Simple random sampling, determination of sample size, inverse sampling, stratified sampling, cluster sampling and systematic sampling;
- Estimation using ratio and regression estimators;
- Estimation using multistage design, double sampling.

VII. Suggested Reading

- Cochran WG. 1977. *Sampling Techniques*. John Wiley.
- Murthy MN. 1977. *Sampling Theory and Methods*. 2nd Ed. Statistical Publ. Soc., Calcutta.
- Singh D, Singh P and Kumar P. 1982. *Handbook on Sampling Methods*. IASRI Publ.

- Sukhatme PV, Sukhatme BV, Sukhatme S and Asok C. 1984. *Sampling Theory of Surveys with Applications*. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.
- Cochran WG. 2007. *Sampling Techniques*, 3rd Edition. John Wiley & Sons Publication

I. **Course Title : Applied Regression Analysis**

II. **Course Code : STAT 521**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

This course is meant for students of all disciplines including agricultural and animal sciences. The students would be exposed to the concepts of correlation and regression. Emphasis will be laid on diagnostic measures such as autocorrelation, multi collinearity and heteroscedasticity. This course would prepare students to handle their data for analysis and interpretation.

V. **Theory**

Unit I

Introduction to correlation analysis and its measures, Correlation from grouped data, correlation, Rank correlation, Testing of population correlation coefficients; Multiple and partial correlation coefficients and their testing.

Unit II

Problem of correlated errors; Auto correlation; Heteroscedastic models, Durbin Watson Statistics; Removal of auto correlation by transformation; Analysis of collinear data; Detection and correction of multi collinearity, Regression analysis; Method of least squares for curve fitting; Testing of regression coefficients; Multiple and partial regressions.

Unit III

Diagnostic of multiple regression equation; Concept of weighted least squares; regression equation on grouped data; Various methods of selecting the best regression equation.

Unit IV

Concept of nonlinear regression and fitting of quadratic, exponential and power curves; Economic and optimal dose, Orthogonal polynomial.

VI. **Practical**

- Correlation coefficient, various types of correlation coefficients, partial and multiple, testing of hypotheses;
- Multiple linear regression analysis, partial regression coefficients, testing of hypotheses, residuals and their applications in outlier detection;
- Handling of correlated errors, multi collinearity;
- Fitting of quadratic, exponential and power curves, fitting oforthogonal polynomials.

VII. **Suggested Reading**

- Kleinbaum DG, Kupper LL, Nizam A. 2007. *Applied Regression Analysis and Other Multivariable Methods* (Duxbury Applied) 4th Ed.

- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Ezekiel M. 1963. *Methods of Correlation and Regression Analysis*. John Wiley.
- Koutsoyiannis A. 1978. *Theory of Econometrics*. MacMillan.
- Kutner MH, Nachtsheim CJ and Neter J. 2004. *Applied Linear Regression Models*. 4th Ed. With Student CD. McGraw Hill.

I. **Course Title : Data Analysis Using Statistical Packages**

II. **Course Code : STAT 522**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

This course is meant for exposing the students in the usage of various statistical packages for analysis of data. It would provide the students a hands on experience in the analysis of their research data. This course is useful to all disciplines.

V. **Theory**

Unit I

Introduction to various statistical packages: Excel, R, SAS, SPSS. Data Preparation; Descriptive statistics; Graphical representation of data, Exploratory data analysis.

Unit II

Test for normality; Testing of hypothesis using chi-square, *t* and *F* statistics and Z-test.

Unit III

Data preparation for ANOVA and ANCOVA, Factorial Experiments, contrast analysis, multiple comparisons, Analyzing crossed and nested classified designs.

Unit IV

Analysis of mixed models; Estimation of variance components; Correlation and regression analysis, Probit, Logit and Tobit Models.

Unit V

Discriminant function; Factor analysis; Principal component analysis; Analysis of time series data, Fitting of non-linear models; Neural networks.

VI. **Practical**

- Use of software packages for summarization and tabulation of data, obtaining descriptive statistics, graphical representation of data;
- Testing the hypothesis for one sample *t*-test, two sample *t*-test, paired *t*-test, test for large samples - Chi-squares test, F test, one-way analysis of variance;
- Designs for Factorial Experiments, fixed effect models, random effect models, mixed effect models, estimation of variance components;
- Linear regression, Multiple regression, Regression plots;
- Discriminant analysis - fitting of discriminant functions, identification of important variables;

- Factor analysis. Principal component analysis - obtaining principal component.

VII. Suggested Reading

- Anderson C.W. and Loynes R.M. 1987. *The Teaching of Practical Statistics*. John Wiley.
- Atkinson A.C. 1985. *Plots Transformations and Regression*. Oxford University Press.
- Chambers J.M., Cleveland W.S., Kleiner B and Tukey P.A. 1983. *Graphical Methods for Data Analysis*. Wadsworth, Belmount, California.
- Chatfield C. 1983. *Statistics for Technology*. 3rd Ed. Chapman & Hall. Chatfield C. 1995.*Problem Solving: A Statistician's Guide*. Chapman & Hall.
- Cleveland W.S. 1985. *The Elements of Graphing Data*. Wadsworth, Belmont, California.
- Ehrenberg ASC. 1982. *A Primer in Data Reduction*. John Wiley.
- Erickson B.H. and Nosanchuk T.A. 1992. *Understanding Data*. 2nd Ed. Open University Press, Milton Keynes.
- Snell E.J. and Simpson HR. 1991. *Applied Statistics: A Handbook of GENSTAT Analyses*.Chapman and Hall.
- Sprent P. 1993. *Applied Non-parametric Statistical Methods*. 2nd Ed. Chapman & Hall.
- Tufte ER. 1983. *The Visual Display of Quantitative Information*. Graphics Press, Cheshire, Conn.
- Velleman PF and Hoaglin DC. 1981. *Application, Basics and Computing of Exploratory Data Analysis*. Duxbury Press.
- Weisberg S. 1985. *Applied Linear Regression*. John Wiley.
- Wetherill GB. 1982. *Elementary Statistical Methods*. Chapman & Hall.
- Cleveland WS. 1994. *The Elements of Graphing Data*, 2nd Ed., Chapman & Hall
- http://freestatistics.altervista.org/en/learning.php.
  http://freestatistics.altervista.org/en/stat.php.
  http://www.cas.lancs.ac.uk/glossary_v1.1/main.html.
  http://www.stat.sc.edu/~grego/courses/stat706/.
- www.drs.icar.gov.in.

I. **Course Title : Applied Genetic Statistics**

II. **Course Code : STAT 523**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

This course is proposed by considering the requirement of students of Plant Breeding and Genetics, Biotechnology and Horticulture who are interested to study the application of Statistics to Genetics and Molecular applications.

V. **Theory**

UNIT I

Mendelian ratios and their testing, Linkage, detection and estimation, Equilibrium population and Hardy Weinberg law. Inbreeding, Inbreeding coefficient and Coefficient of Parentage, Inbreeding under regular systems of mating, Estimation and testing of Heterosis.

UNIT II

Average effect of a gene, Breeding value, Estimation of Genetic components of variation, Heritability and Repeatability, Estimation of Phenotypic, Genotypic and Environmental correlations. Selection, Individual and pedigree selection.

UNIT III

Designs for plant breeding trials- Compact family block designs, square and rectangular lattice designs. Multivariate analysis of variance, Cluster analysis, Similarity algorithms and Clustering methods for qualitative and quantitative data, Principal component analysis, Principal co-ordinate analysis,

UNIT IV

Multiple correlations, Regression and Path analysis, Discriminant analysis, Selection indices, Generation mean analysis

UNIT V

Analysis of Genotype X environment interactions, Measurement of stability and adaptability-Linear and nonlinear approaches. Combining ability, Analysis of designs for Diallel, Partial diallel and line x tester crosses.

VI. Practical

- Mendelian ratios and their testing
- Finding linkage in coupling and repulsion phase.
- Detection of linkage (χ 2 test)- Recombination fraction.
- Estimation of linkage, different methods, Gene and Genotypic frequency, Random mating population, Hardy Weinberg law
- Resemblance between individuals, Inbreeding, inbreeding coefficient and coefficient of parentage.
- Inbreeding under regular systems of mating. Heterosis- Breeding value, Estimation of Genetic components of variation.
- Heritability and repeatability, Estimation of Phenotypic, genotypic and Environmental correlations
- Analysis of data with different type of crosses
- Partitioning of sum of squares into components- Compact family block designs, Lattice designs – construction and analysis , Similarity and divergence measures.
- Clustering methods for qualitative and quantitative data- Dendrogram, Metroglyphs, D^2
- Principal component analysis and Principal co-ordinate analysis, Discriminant functions and selection indices.
- Generation mean analysis.
- Path analysis, Stability analysis- Linear and nonlinear methods. Combining ability and Diallel analysis
- Line X tester analysis

VII. Suggested reading:

- Cochran W.G. and Cox, D. R. (1957). *Experimental Designs*, John Wiley
- Dabholkar, A.R. (1992) Elements of Biometrical Genetics. Concept Publishing Company, New Delhi
- Das, M.N. and Giri, N.C. (1991) *Design and Analysis of Experiments* Wiley Eastern, New Delhi
- Falconer, D.S. (1985). *Introduction to Quantitative Genetics*, English Language Book Society, Longman

- Jain, J.P. (1991). *Statistical Techniques in Quantitative Genetics*, Hindusthan Publishing Company, New Delhi
- Kempthorne, O. (1957). *An introduction to Genetic Statistics*, The Iowa State University Press, London
- Kempthorne, O. (1976). *Design and analysis of Experiments*, John Wiley
- Krzanowski, W.J. (1988). *'Principles of Multivariate analysis* – A user's Perspective' Clarendon Press-Oxford Statistical Science Series.
- Li, C.C. (1982). *Population Genetics*. The University of Chicago Press
- Mather, K. and Jinks J.L. (1977). *Introduction to Biometrical Genetics*, Chapman and Hall
- Montgomery, D.C. (2005) *Design and Analysis of Experiments*, John Wiley.
- Nageswara Rao, G. (2007) *Statistics for Agricultural Sciences*, B.S. Publications,
- Narain, P. (1990). *Statistical Genetics*, Wiley Eastern, New Delhi Hyderabad
- Percus, J.K. (2001). *Mathematics of Genome analysis*, Cambridge University Press
- Singh, R.K. and Chaudhary, B.D. 1985. *Biometrical methods in quantitative Genetic analysis* Kalyani Publishers, Ludhiana
- Stansfield W.D. (1991). *Theory and problems of Genetics*, Scahum's Outline Series.

I. Course Title : Applied Multivariate Analysis

II. Course Code : STAT 524

III. Credit Hours : 1+1

IV. Aim of the course

This course is proposed by considering the application of several multivariate methods to research problems in the extension studies, plant breeding and in almost all the field of studies. Moreover, this course aims to have better understanding of various multivariate methods and the identification the situation wherein each one is applied.

V. Theory

Unit I

Introduction to multivariate data, meaning of multivariate mean vector, variance-covariance matrix, and correlation matrix. Inferences about multivariate mean vector, variance-covariance matrix. Multivariate analysis of variance (MANOVA) and its applications to various research problems.

Unit II

Measurement scale, types of variables- quantitative, qualitative, categorical, and binary variables and handling with multivariate data. The concept of standardisation of variables, various standardisation methods, and construction of index based on multidimensional data, Outlier detection of multivariate data using Box-plot and multiple regression analysis-linear and non-linear regression models and its interpretation.

Unit III

Principal component analysis – estimation of principal components using software's, principal component scores, score plots bi-plots and 3D plots of principal component scores etc using SPSS. Factor analysis- factor loadings, communality, loading plots, Interpretation of factor analysis using factor loadings, communality and loading plots. Application of PCA and factor analysis in social science, plant science, etc. Classification based on linear discriminated function and grouping of objects using Cluster analysis-hierarchical and Non-hierarchical Cluster analysis- Similarity/dissimilarity measures for quantitative, qualitative, binary and mixed type of data, and dendrograms.

Unit IV

Simple, partial and multiple correlations, Canonical correlation analysis - Meaning of canonical variate, canonical correlation and its test of significance, structure coefficients, Redundancy coefficient - application and interpretation of results using structure coefficients, canonical loadings and cross loadings and the meaning of redundancy.

VI. Practical:

- Testing of hypothesis on mean vectors of multivariate normal population, multivariate analysis of variance and covariance
- Multiple regression analysis – linear and non- linear analysis, Principal component analysis and Factor analysis, Cluster analysis – Hierarchical and non- hierarchical, Problems on Simple, partial and multiple correlation coefficients, Canonical Correlation and its test of significance
- Analysis of sample data may be performed using any of the statistical Software's including SPSS, SAS, or R

VII. Suggested readings:

- Testing of hypothesis on mean vectors of multivariate normal population, multivariate analysis of variance and covariance
- Anderson T W .1984. *An Introduction to Multivariate Statistical Analysis*. 2nd Ed. John Wiley
- Giri N C. 1977. *Multivariate Statistical Inference*. Academic press
- Johnson R A & Wilchern D W.1988. *Applied Multivariate Statistical Analysis*. Prentice Hall.
- Rencher A C. 2002. *Methods of Multivariate Analysis* .2nd Ed. John Wiley
- Srivastava MS & Khatri CG. 1979. *An Intoduction to Multivariate Statistics*. North Holland.

I. **Course Title : Mathematics-I**

II. **Course Code : STAT 551**

III. **Credit Hours : 3+0**

IV. **Aim of the course**

This course lays the foundation of all other courses of Agricultural Statistics discipline by preparing them to understand the importance of mathematical methods in research. The students would be exposed to the basic mathematical tools of real analysis, calculus, differential equations and numerical analysis. This would prepare them to study their main courses that involve knowledge of Mathematics.

V. **Theory**

Unit I

Calculus: Limit and continuity, differentiation of functions, successive differentiation, partial differentiation, mean value theorems, Taylor and Maclaurin's series. Application of derivatives, L'hospital's rule.

Unit II

Real Analysis: Convergence and divergence of infinite series, use of comparison tests -D'Alembert's Ratio - test, Cauchy's nth root test, Raabe's test, Kummer's test, Gauss test. Absolute and conditional convergence. Riemann integration, concept of Lebesgue integration, power series, Fourier, Laplace and Laplace -Steiltjes' transformation, multiple integrals. Integration of rational, irrational and trigonometric functions. Application of integration.

Unit III

Differential equation: Differential equations of first order, linear differential equations of higher order with constant coefficient.

Unit IV

Numerical Analysis: Simple interpolation, Divided differences, Numerical differentiation and integration.

VI. Suggested Reading

- Bartle RG. 1976. *Elements of Real Analysis*. John Wiley. Chatterjee SK. 1970. *Mathematical Analysis*. Oxford & IBH.
- Gibson GA. 1954. *Advanced Calculus*. Macmillan.
- Henrice P. 1964. *Elements of Numerical Analysis*. John Wiley.
- Hildebrand FB. 1956. *Introduction to Numerical Analysis*. Tata McGraw Hill.
- Priestley HA. 1985. *Complex Analysis*. Clarenton Press.
- Rudin W. 1985. *Principles of Mathematical Analysis*. McGraw Hill. Sauer T. 2006. *Numerical Analysis With CD-Rom*. Addison Wesley. Scarborough JB. 1976. *Numerical Mathematical Analysis*. Oxford & IBH. Stewart J. 2007. *Calculus.* Thompson.
- Thomas GB Jr. and Finney RL. 1996. *Calculus*. 9^{th} Ed. Pearson Edu.

I. Course Title : Probability Theory

II. Course Code : STAT 552

III. Credit Hours : 2+0

IV. Aim of the course

This is a fundamental course in Statistics. This course lays the foundation of probability theory, random variable, probability distribution, mathematical expectation, etc. which forms the basis of basic statistics. The students are also exposed to law of large numbers and central limit theorem. The students also get introduced to stochastic processes.

V. Theory

Unit I

Basic concepts of probability. Elements of measure theory: class of sets, field, sigma field, minimal sigma field, Borel sigma field in R, measure-probability measure. Axiomatic approach to probability. Properties of probability based on axiomatic definition. Addition and multiplication theorems. Conditional probability and independence of events. Bayes theorem.

Unit II

Random variables: definition of random variable, discrete and continuous, functions of random variables. Probability mass function and Probability density function, Distribution function and its properties. Notion of bivariate random variables, bivariate distribution function and its properties. Joint, marginal and conditional distributions. Independence of random variables. Transformation of random variables (two-dimensional case only). Mathematical expectation: Mathematical expectation of functions of a random variable. Raw and central moments and their relation, covariance, skewness and kurtosis. Addition and multiplication theorems of expectation. Definition of moment generating function, cumulating generating function, probability generating function and statements of their properties.

Unit III

Conditional expectation and conditional variance. Characteristic function and its properties. Inversion and uniqueness theorems. Chebyshev, Markov, Cauchy- Schwartz, Sequence of random variables and modes of convergence (convergence in distribution in probability, almost surely, and quadratic mean) and their interrelations.

Unit IV

Laws of large numbers: WLLN, Bernoulli and Kintchin's WLLN. Kolmogorov inequality, Kolmogorov's SLLNs.Central Limit theorems: Demoviere- Laplace CLT, Lindberg – Levy CLT and simple applications.

VI. Suggested Reading

- Ash RB. 2000. *Probability and Measure Theory*. 2nd Ed. Academic Press. Billingsley P. 1986. *Probability and Measure*. 2nd Ed. John Wiley.
- Capinski M and Zastawniah. 2001. *Probability Through Problems*. Springer. Dudewicz EJ & Mishra SN. 1988. *Modern Mathematical Statistics*. John Wiley.
- Feller W. 1972. *An Introduction to Probability Theory and its Applications*. Vols. I., II. John Wiley.
- Loeve M. 1978. *Probability Theory*. 4th Ed. Springer.
- Marek C, Tomasz JZ. 2003. *Probability* Through Problems (Problem Books in Mathematics) Corrected Ed.
- Marek F. 1963. *Probability Theory and Mathematical Statistics*. John Wiley.
- Rohatgi VK & Saleh AK Md. E. 2005. *An Introduction to Probability and* Statistics. 2nd Ed. John Wiley.

I. Course Title : Statistical Methods

II. Course Code : STAT 553

III. Credit Hours : 2+1

IV. Aim of the course

This course lays the foundation of probability distributions and sampling distributions and their application which forms the basis of Statistical Inference. Together with probability theory, this course is fundamental to the discipline of Statistics. The students are also exposed to correlation and regression, and order statistics and their distributions. Categorical data analysis is also covered in this course.

V. Theory

Unit I

Descriptive statistics: probability distributions: Discrete probability distributions ~ Bernoulli, Binomial, Poisson, Negative-binomial, Geometric and Hyper Geometric, uniform, multinomial ~ Properties of these distributions and real life examples. Continuous probability distributions ~ rectangular, exponential, Cauchy, normal, gamma, beta of two kinds, Weibull, lognormal, logistic, Pareto. Properties of these distributions. Probability distributions of functions of random variables.

Unit II

Concepts of compound, truncated and mixture distributions (definitions and examples). Sampling distributions of sample mean and sample variance from Normal population, central and non–central chi-Square, *t* and *F* distributions, their properties and inter relationships.

Unit III

Concepts of random vectors, moments and their distributions. Bivariate distributions - marginal and conditional distributions, Distribution of quadratic forms and Cochran theorem.

Unit IV

Correlation, Rank Correlation, correlation ratio and intra-class correlation, Regression analysis- linear and multiple regression, partial and multiple correlation, categorical data analysis and association between variables.

Unit V

Order statistics, distribution of r-th order statistics, joint distribution of several order statistics and their functions, marginal distributions of order statistics.

VI. Practical

- Fitting of discrete distributions and test for goodness of fit;
- Fitting of continuous distributions and test for goodness of fit; Fitting of truncated distribution;
- Computation of simple, multiple and partial correlation coefficient, correlation ratio and intra-class correlation;
- Regression coefficients and regression equations;
- Fitting of Pearsonian curves;
- Analysis of association between attributes, categorical data and log-linear models.

VII. Suggested Reading

- Agresti, A. 2012. *Categorical Data Analysis* 3rd Ed. John Wiley.
- Arnold BC, Balakrishnan N and Nagaraja HN. 1992. *A First Course in Order Statistics*. JohnWiley.
- David HA and Nagaraja HN. 2003. *Order Statistics*. 3rd Ed. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. *Modern Mathematical Statistics*. John Wiley.
- Huber PJ. 1981. *Robust Statistics*. John Wiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. *Continuous Univariate*

Distributions. JohnWiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. *Discrete Univariate Distributions*. JohnWiley.
- Marek F.1963. *Probability Theory and Mathematical Statistics*. John Wiley.
- Rao CR. 1965. *Linear Statistical Inference and its Applications*. John Wiley.
- Rohatgi VK and Saleh AK Md. E. 2005. *An Introduction to Probability and Statistics*. 2nd Ed. John Wiley.
- Gupta. S.P 2008. *Statistical Methods*. Sultan Chand & sons Educational Publisher

I. Course Title : Actuarial Statistics

II. Course Code : STAT 554

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant to expose to the students to the statistical techniques such as probability models, life tables, insurance and annuities. The students would also be exposed top practical applications of these techniques in computation of premiums that include expenses, general expenses, types of expenses and per policy expenses.

V. Theory

Unit I

Insurance and utility theory, models for individual claims and their sums, survival function, curtate future lifetime, force of mortality.

Unit II

Life table and its relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables.

Unit III

Multiple life functions, joint life and last survivor status, insurance and annuity benefits through multiple life functions evaluation for special mortality laws. Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrement, net single premiums and their numerical evaluations.

Unit IV

Distribution of aggregate claims, compound Poisson distribution and its applications.

Unit V

Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding.

Unit VI

Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance, recursions, commutation functions.

Unit VII

Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions, varying annuities, recursions, complete annuities-immediate and apportionable annuities-due.

Unit VIII

Net premiums: Continuous and discrete premiums, true monthly payment premiums, apportionable premiums, commutation functions, accumulation type benefits. Payment premiums, apportionable premiums, commutation functions, accumulation type benefits. Net premium reserves: Continuous and discrete net premium reserve, reserves on a semi-continuous basis, reserves based on true monthly premiums, reserves on an apportionable or discounted continuous basis, reserves at fractional durations, allocations of loss to policy years, recursive formulas and differential equations for reserves, commutation functions.

Unit IX

Some practical considerations: Premiums that include expenses-general expenses types of expenses, per policy expenses. Claim amount distributions, approximating the individual model, stop-loss insurance.

VI. Suggested Reading

- Atkinson ME and Dickson DCM. 2000. *An Introduction to Actuarial Studies*. Elgar Publ.
- Bedford T and Cooke R. 2001. *Probabilistic Risk Analysis*. Cambridge.
- Booth PM, Chadburn RG, Cooper DR, Haberman, S and James DE.1999. Modern *Actuarial Theory and Practice*. Chapman & Hall.
- Borowiak Dale S. 2003. *Financial and Actuarial Statistics: An Introduction.* Marcel Dekker.
- Bowers NL, Gerber HU, Hickman JC, Jones DA and Nesbitt CJ.1997. *Actuarial Mathematics*. 2nd Ed. Society of Actuaries, Ithaca, Illinois.
- Dale SB, Arnold FS. 2013. *Financial and Actuarial Statistics: An Introduction*, 2nd Ed. (Statistics: A Series of Textbooks and Monogrphs)
- Daykin CD, Pentikainen T and Pesonen M. 1994. *Practical Risk Theory for Actuaries*. Chapman & Hall.
- Klugman SA, Panjer HH, Willmotand GE and Venter GG. 1998. *Loss Models: From data to Decisions*. John Wiley.
- Medina PK and Merino S. 2003. *Mathematical Finance and Probability: A Discrete Introduction*. Basel, Birkhauser.
- Melnikov, A. 2011. *Risk Analysis in Finance and Insurance* (Chapman & Hall/Crc Financial Mathematics Series) 2nd Ed.
- Neill A. 1977. *Life Contingencies*. Butterworth-Heinemann.
- Rolski T, Schmidli H, Schmidt V and Teugels J. 1998. *Stochastic Processes for Insurance and Finance*. John Wiley.
- Rotar VI. 2006. *Actuarial Models. The Mathematics of Insurance*. *Chapman*& Hall/CRC.
- Spurgeon ET. 1972. *Life Contingencies*. Cambridge Univ. Press.

I. **Course Title** : **Bioinformatics**

II. **Course Code** : **STAT 555**

III. **Credit Hours** : **2+0**

IV. **Aim of the course**

Bioinformatics is a new emerging area. It is an integration of Statistics, Computer applications and Biology. The trained manpower in the area of Bioinformatics is required for meeting the new challenges in teaching and research in the discipline of Agricultural Sciences. This course is meant to train the students on concepts of basic biology, statistical techniques and computational techniques for understanding bioinformatics principals.

V. **Theory**

Unit I

Basic Biology: Cell, genes, gene structures, gene expression and regulation, Molecular tools, nucleotides, nucleic acids, markers, proteins and enzymes, bioenergetics, single nucleotide polymorphism, expressed sequence tag. Structural and functional genomics: Organization and structure of genomes, genome mapping, assembling of physical maps, strategies and techniques for genome sequencing and analysis.

Unit II

Computing techniques: OS and Programming Languages – *Linux, perl, bioperl, python, biopythn, cgi, MySQL, phpMyAdmin*; Coding for browsing biological databases on web, parsing & annotation of genomic sequences; Database designing; Computer networks – Internet, World wide web, Web browsers– EMBnet, NCBI; Databases on public domain pertaining to Nucleic acid sequences, protein sequences, SNPs, etc.; Searching sequence databases, Structural databases.

Unit III

Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing; Resampling techniques – Bootstrapping and Jack-knifing; Hidden Markov Models; Bayesian estimation and Gibbs sampling;

Unit IV

Tools for Bioinformatics: DNA Sequence Analysis – Features of DNA sequence analysis, Approaches to EST analysis; Pairwise alignment techniques: Comparing two sequences, PAM and BLOSUM, Global alignment (The Needleman and Wunsch algorithm), Local Alignment (The Smith-Waterman algorithm), Dynamic programming, Pairwise database searching; Sequence analysis– BLAST and other related tools, Multiple alignment and database search using motif models, ClustalW, Phylogeny; Databases on SNPs; EM algorithm and other methods to discover common motifs in bio sequences; Gene prediction based on Neural Networks, Genetic algorithms, Computational analysis of protein sequence, structure and function; Design and Analysis of microarray/ RNA seqexperiments.

VI. **Suggested Reading**

- Baldi P. and Brunak S. 2001. *Bioinformatics: The Machine Learning Approach.* 2nd Ed. (Adaptive Computation and Machine Learning). MIT Press.
- Baxevanis A.D. and Francis B.F. (Eds.). 2004. *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins*. John Wiley.
- Bergeron B.P. 2002. *Bioinformatics Computing*. Prentice Hall.
- Duda R.O, Hart P.E and Stork D.G. 1999. *Pattern Classification*. John Wiley.
- Ewens W.J and Grant G.R. 2001. *Statistical Methods in Bioinformatics: An Introduction* (*Statistics for Biology and Health*). Springer.
- Graham B. Zweig, J. Buffett, WE. 2006.*The Intelligent Investor: The Definitive Book on Value Investing.* A Book of Practical Counsel, Revised Edition
- Hunt S and Livesy F. (Eds.). 2000. *Functional Genomics: A Practical Approach* (*The Practical Approach Series, 235*). Oxford Univ. Press.
- Jones N.C. and Pevzner P.A. 2004. *An Introduction to Bioinformatics Algorithims*. MIT Press.
- Koski T and Koskinen T. 2001. *Hidden Markov Models for Bioinformatics*. Kluwer.
- Krane D.E. and Raymer M.L. 2002. *Fundamental Concepts of Bio-informatics*. Benjamin / Cummings.
- Krawetz S.A and Womble D.D. 2003. *Introduction to Bioinformatics: A Theoretical and Practical Approach*. Humana Press.
- Lesk A.M. 2002. *Introduction to Bio-informatics*. Oxford Univ. Press.
- Percus J.K. 2001. *Mathematics of Genome Analysis*. Cambridge Univ. Press.
- Sorensen D and Gianola D. 2002. *Likelihood, Bayesian and MCMC Methods in Genetics.*Springer.
- Tisdall J.D. 2001. *Mastering Perl for Bioinformatics*. O'Reilly & Associates.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. *Data Mining in Bioinformatics*. Springer.
- Wu C.H. and McLarty J.W. 2000. *Neural Networks and Genome Informatics*. Elsevier.
- Wunschiers R. 2004. *Computational Biology Unix/Linux, Data Processing and Programming*. Springer.

I. **Course Title : Econometrics**

II. **Course Code : STAT 556**

III. **Credit Hours : 2+0**

IV. **Aim of the course**

This course is meant for training the students in econometric methods and their applications in agriculture. This course would enable the students in understanding the economic phenomena through statistical tools and economics principles.

V. Theory

Unit I

Representation of Economic phenomenon, relationship among economic variables, linear and non-linear economic models, single equation general linear regression model, basic assumptions, Ordinary least squares method of estimation for simple and multiple regression models; summary statistics correlation matrix, co-efficient of multiple determination, standard errors of estimated parameters, tests of significance and confidence interval estimation. BLUE properties of Least Squares estimates. Chow test, test of improvement of fit through additional regressors. Maximum likelihood estimation.

Unit II

Heteroscedasticity, Auto-correlation, Durbin Watson test, Multi-collinearity. Stochastic regressors, Errors in variables, Use of instrumental variables in regression analysis. Dummy Variables. Distributed Lag models: Koyck's Geometric Lag scheme, Adaptive Expectation and Partial Adjustment Mode, Rational Expectation Models and test for rationality.

Unit III

Simultaneous equation model: Basic rationale, Consequences of simultaneous relations, Identification problem, Conditions of Identification, Indirect Least Squares, Two-stage least squares, K-class estimators, Limited Information and Full Information Maximum Likelihood Methods, three stage least squares, Generalized least squares, Recursive models, SURE Models. Mixed Estimation Methods, use of instrumental variables, pooling of cross-section and time series data, Principal Component Methods.

Unit IV

Problem and Construction of index numbers and their tests; fixed and chain based index numbers; Construction of cost of living index number.

Unit V

Demand analysis – Demand and Supply Curves; Determination of demand curves from market data. Engel's Law and the Engel's Curves, Income distribution and method of its estimation, Pareto's Curve, Income inequality measures.

VI. Suggested Reading

- Croxton F.E. and Cowden D.J. 1979. *Applied General Statistics*. Prentice Hall of India.
- James H.S. and Mark W.W. 2017. Introduction to Econometrics, 3rd Ed. John Wiley
- Johnston J. 1984. *Econometric Methods*. McGraw Hill.
- Judge G.C., Hill R.C., Griffiths W.E., Lutkepohl H and Lee T.C. 1988. *Introduction to the Theory and Practice of Econometrics*. 2nd Ed. John Wiley.
- Kmenta J. 1986. *Elements of Econometrics*. 2nd Ed. University of Michigan Press.
- Koop G. 2007. *Introduction to Econometrics*. John Wiley.

- Maddala G.S. 2001. *Introduction to Econometrics*. 3rd Ed. John Wiley.
- Pindyck R.S. and Rubinfeld D.L. 1998. *Econometric Models and Economic Forecasts*. 4th Ed. McGraw Hill.
- Verbeek M. 2008. *A Guide to Modern Econometrics*. 3rd Ed. John Wiley.

I. **Course Title : Mathematics-II**

II. **Course Code : STAT 561**

III. **Credit Hours : 2+0**

IV. **Aim of the course**

This is another course that supports all other courses in Agricultural Statistics. The students would be exposed to the advances in Linear Algebra and Matrix theory. This would prepare them to study their main courses that involve knowledge of Linear Algebra and Matrix Algebra.

V. **Theory**

Unit I

Linear Algebra: Group, ring, field and vector spaces, Sub-spaces, basis, Gram Schmidt's orthogonalization, Galois field - Fermat's theorem and primitive elements. Linear transformations. Graph theory: Concepts and applications.

Unit II

Matrix Algebra: Basic terminology, linear independence and dependence of vectors. Row and column spaces, Echelon form. Determinants, Trace of matrices rank and inverse of matrices. Special matrices – idempotent, symmetric, orthogonal. Eigen values and eigen vectors, Spectral decomposition of matrices.

Unit III

Unitary, Similar, Hadamard, Circulant, Helmert's matrices. Kronecker and Hadamard product of matrices, Kronecker sum of matrices. Sub-matrices and partitioned matrices, Permutation matrices, full rank factorization, Grammian root of a symmetric matrix. Solution of linear equations, Equations having many solutions.

Unit IV

Generalized inverses, Moore-Penrose inverse, Applications of g-inverse.
Inverse and Generalized inverse of partitioned matrices, Differentiation and integration of vectors and matrices, Quadratic forms.

VI. **Suggested Reading**

- Aschbacher M. 2000. *Finite Group Theory*. Cambridge University Press.
- Deo N. 1984. *Graph Theory with Application to Engineering and Computer Science*. Prentice Hall of India.
- Gentle JE. 2007. *Matrix Algebra: Theory, Computations and Applications in Statistics*.Springer.
- Graybill FE.1961. *Introduction to Matrices with Applications in Statistics*. Wadsworth Publ.
- Hadley G. 1969. *Linear Algebra*. Addison Wesley.

- Harville DA. 1997. *Matrix Algebra from a Statistician's Perspective*. Springer.
- Rao CR. 1965. *Linear Statistical Inference and its Applications*. 2nd Ed. John Wiley.
- Robinson DJS. 1991. *A Course in Linear Algebra with Applications*. World Scientific.
- Searle SR. 2006. *Matrix Algebra Useful for Statistics* John Wiley, 2nd Ed.
- Seber GAF. 2008. *A Matrix Handbook for Statisticians*. John Wiley.

I. Course Title : Statistical Inference

II. Course Code : STAT 562

III. Credit Hours : 2+1

IV. Aim of the course

This course lays the foundation of Statistical Inference. The students would be taught the problems related to point and confidence interval estimation and testing of hypothesis. They would also be given the concepts of nonparametric and sequential test procedures and elements of decision theory.

V. Theory

Unit I

Concepts of point estimation: unbiasedness, consistency, efficiency and sufficiency. Statement of Neyman's Factorization theorem with applications. MVUE, Rao- Blackwell theorem, completeness, Lehmann- Scheffe theorem. Fisher information, Cramer-Rao lower bound and its applications.

Unit II

Moments, minimum chi-square, least square and maximum likelihood methods of estimation and their properties. Bayesian estimation. Interval estimation-Confidence level, shortest length CI.CI for the parameter of Normal distribution, Bayesian distribution, Exponential, Binomial and Poisson.

Unit III

Fundamentals of hypothesis testing-statistical hypothesis, statistical test, critical region, types of errors, test function, randomized and non- randomized tests, level of significance, power function, most powerful tests: Neyman-Pearson fundamental lemma, MLR families and UMP tests for one parameter exponential families. Concepts of consistency, unbiasedness and invariance of tests. Likelihood Ratio tests, asymptotic properties of LR tests with applications (including homogeneity of means and variances). Relation between confidence interval estimation and testing of hypothesis.

Unit IV

Sequential Probability ratio test, Properties of SPRT. Termination property of SPRT, SPRT for Binomial, Poisson, Normal and Exponential distributions, admissible and optimal decision functions, estimation and testing viewed as decision problems, conjugate families, Bayes and Minimax decision functions with applications to estimation with quadratic loss.

Unit V

Non-parametric tests: Sign test, Wilcoxon signed rank test, Runs test for randomness, Kolmogorov – Smirnov test for goodness of fit, Median test and Wilcoxon-Mann-Whitney U-test. Chi-square test for goodness of fit and test for independence of attributes. Spearman's rank correlation and Kendall's Tau tests for independence. Kruskal Wallis Test and Friedman's non-parametric tests

VI. Practical

- Methods of estimation – Maximum Likelihood, Minimum 2 and Moments;
- Confidence Interval Estimation;
- MP and UMP tests;
- Large Sample tests;
- Non-parametric tests, Sequential Probability Ratio Test;
- Kruskal Wallis Test and Friedman's non-parametric tests

VII. Suggested Reading

- Box G.E.P. and Tiao G.C. 1992. *Bayesian Inference in Statistical Analysis*. John Wiley.
- Casela G and Berger R.L. 2001. *Statistical Inference*. Duxbury Thompson Learning.
- Christensen R. 1990. *Log Linear Models*. Springer.
- Conover W.J. 1980. *Practical Nonparametric Statistics*. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. *Modern Mathematical Statistics*. John Wiley.
- Gibbons J.D. 1985. *Non Parametric Statistical Inference*. 2^{nd} Ed. Marcel Dekker.
- Kiefer J.C. 1987. *Introduction to Statistical Inference*. Springer.
- Lehmann EL. 1986. *Testing Statistical Hypotheses*. John Wiley.
- Lehmann EL. 1986. *Theory of Point Estimation*. John Wiley.
- Randles R.H and Wolfe D.S. 1979. *Introduction to the Theory of Nonparametric Statistics*. John Wiley.
- Rao C.R. 2009. *Linear Statistical Inference and Its Applications*, 3^{rd} Ed. John Wiley.
- Rohatgi V.K. and Saleh A.K. Md. E. 2005. *An Introduction to Probability and Statistics*. 2^{nd} Ed. John Wiley.
- Rohtagi V.K. 1984. *Statistical Inference*. John Wiley
- Sidney S and Castellan N.J. Jr. 1988. *Non Parametric Statistical Methods for Behavioral Sciences*. McGraw Hill.
- Wald A. 2004. *Sequential Analysis*. Dover Publ.
- Michael J.Panik. 2012. *Statistical Inference.* A John Wiley & Sons, INC, publication

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I. Course Title : Design of Experiments

II. Course Code : STAT 563

III. Credit Hours : 2+1

IV. Aim of the course

Design of Experiments provides the statistical tools to get maximum information from least amount of resources. This course is meant to expose the students to the basic principles of design of experiments. The students would also be provided with mathematical background of various basic designs involving one-way and two-way elimination of heterogeneity and their characterization properties. This course would also prepare the students in deriving the experimental data.

V. Theory

Unit I

Elements of linear estimation, Gauss Markoff Theorem, relationship between BLUEs and linear zero-functions. Aitken’s transformation, test of hypothesis, Analysis of Variance, Partitioning of degrees of freedom.

Unit II

Orthogonality, contrasts, mutually orthogonal contrasts, analysis of covariance; Basic principles of design of experiments, uniformity trials, size and shape of plots and blocks, Randomization procedure.

Unit III

Basic designs - completely randomized design, randomized complete block design and Latin square design; Construction of orthogonal Latin squares, mutually orthogonal Latin squares (MOLS), Youden square designs, Graeco Latin squares.

Unit IV

Balanced Incomplete Block (BIB) designs – general properties and analysis without and with recovery of intra block information, construction of BIB designs. Partially balanced incomplete block designs with two associate classes - properties, analysis and construction, Lattice designs, alpha designs, cyclic designs, augmented designs.

Unit V

Factorial experiments, confounding in symmetrical factorial experiments (2^n and 3^n series), partial and total confounding, asymmetrical factorials.

Unit VI

Cross-over designs. Missing plot technique; Split plot and Strip plot design; Groups of experiments. Sampling in field experiments.

VI. Practical

- Determination of size and shape of plots and blocks from uniformity trials data;
- Analysis of data generated from completely randomized design, randomized complete block design;
- Latin square design, Youden square design; Analysis of data generated from a BIB design, lattice design, PBIB designs;
- 2^n, 3^n factorial experiments without and with confounding;
- Split and strip plot designs, repeated measurement design;
- Missing plot techniques,
- Analysis of covariance;
- Analysis of Groups of experiments,

- Analysis of clinical trial experiments.

VII. Suggested Reading

- Chakrabarti M.C. 1962. *Mathematics of Design and Analysis of Experiments*. Asia Publ.House.
- Cochran W.G. and Cox D.R. 1957. *Experimental Designs*. 2nd Ed. John Wiley.
- Dean A.M. and Voss D. 1999. *Design and Analysis of Experiments*. Springer.
- Dey A and Mukerjee R. 1999. *Fractional Factorial Plans*. John Wiley.
- Dey A 1986. *Theory of Block Designs*. Wiley Eastern. Hall M Jr. 1986. *Combinatorial Theory*. John Wiley.
- John J.A. and Quenouille M.H. 1977. *Experiments: Design and Analysis*. Charles & Griffin.
- Kempthorne, O. 1976. Design and Analysis of Experiments. John Wiley. Khuri AI & Cornell JA. 1996. *Response Surface Designs and Analysis*. 2nd Ed. Marcel Dekker.
- Kshirsagar A.M. 1983. *A Course in Linear Models*. Marcel Dekker.
- Montgomery D.C. 2013. *Design and Analysis of Experiments*. John Wiley & Sons
- Raghavarao D. 1971. *Construction and Combinatorial Problems in Design of Experiments*. John Wiley.
- Searle S.R. 2006. *Linear Models*. John Wiley.
- Street A.P. and Street D.J. 1987. *Combinatorics of Experimental Designs*. Oxford Science Publ.
- Design Resources Server. *Indian Agricultural Statistics Research Institute (ICAR), New Delhi- 110 012, India*. Hyperlink "http: //www.iasri.res.in/design" www.drs.icar.gov.in.

I. Course Title : Sampling Techniques

II. Course Code : STAT 564

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant to expose the students to the techniques of drawing representative samples from various populations and then preparing them on the mathematical formulations of estimating the population parameters based on the sample data. The students would also be exxposed to the real life applications of sampling techniques and estimation of parameters.

V. Theory

Unit I

Sample survey vs complete enumeration, probability sampling, sample space, sampling design, sampling strategy; Determination of sample size; Confidence-interval; Simple random sampling, Estimation of population proportion, Stratified random sampling, Proportional allocation and optimal allocation, Inverse sampling.

Unit II

Ratio, Product and regression methods of estimation, Cluster sampling, Systematic sampling, Multistage sampling with equal probability, Separate and combined ratio estimator, Double sampling, Successive sampling –two occasions. Unbiased ratio type estimators

Unit III

Non-sampling errors – sources and classification, Non-response in surveys, Randomized response techniques, Response errors/ Measurement error – interpenetrating sub-sampling.

Unit IV

PPS Sampling with and without replacement, Cumulative method and Lahiri's method of selection, Horvitz-Thompson estimator, Ordered and unordered estimators, Sampling strategies due to Midzuno-Sen and Rao-Hartley-Cochran. Inclusion probability proportional to size sampling.

VI. Practical

- Determination of sample size and selection of sample;
- Simple random sampling, Inverse sampling, Stratified random sampling, Cluster sampling, systematic sampling;
- Ratio and regression methods of estimation;
- Double sampling, multi-stage sampling, Imputation methods;
- Randomized response techniques;
- Sampling with varying probabilities.

VII. Suggested Reading

- Cassel C.M., Sarndal C.E. and Wretman J.H. 1977. *Foundations of Inference in Survey Sampling*. John Wiley.
- Chaudhari A and Stenger H. 2005. *Survey Sampling Theory and Methods*. 2nd Ed. Chapman & Hall.
- Chaudhari A and Voss J.W.E. 1988. *Unified Theory and Strategies of Survey Sampling*. North Holland.
- Cochran W.G. 1977. *Sampling Techniques*. John Wiley.
- Hedayat A.S. and Sinha B.K. 1991. *Design and Inference in Finite Population Sampling*. John Wiley.
- Kish L. 1965. *Survey Sampling*. John Wiley.
- Mukhopadhyay, P. 2008.*Theory and Methods of Survey Sampling*, John Wiley & Sons
- Murthy M.N. 1977. *Sampling Theory and Methods*. 2nd Ed. Statistical Publ. Society, Calcutta.
- Sukhatme P.V., Sukhatme B.V., Sukhatme S and Asok C. 1984. *Sampling Theory of Surveys with Applications*. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.
- Thompson SK. 2000. *Sampling*. John Wiley.
- Kochran WG. 2007. *Sampling Techniques*. A John Wiley & Sons *Publication*

I. Course Title : Statistical Genetics

II. Course Code : STAT 565

III. **Credit Hours : 2+1**

IV. **Aim of the course**

This course is meant to prepare the students in applications of statistics in quantitative genetics and breeding. The students would be exposed to the physical basis of inheritance, detection and estimation of linkage, estimation of genetic parameters and development of selection indices.

V. **Theory**

Unit I

Physical basis of inheritance. Analysis of segregation, detection and estimation of linkage for qualitative characters. Amount of information about linkage, combined estimation, disturbed segregation.

Unit II

Gene and genotypic frequencies, Random mating and Hardy -Weinberg law, Application and extension of the equilibrium law, Fisher's fundamental theorem of natural selection. Disequilibrium due to linkage for two pairs of genes, sex-linked genes, Theory of path coefficients.

Unit III

Concepts of inbreeding, Regular system of inbreeding. Forces affecting gene frequency - selection, mutation and migration, equilibrium between forces in large populations, Random genetic drift, Effect of finite population size.

Unit IV

Polygenic system for quantitative characters, concepts of breeding value and dominance deviation. Genetic variance and its partitioning, Effect of inbreeding on quantitative characters, Multiple allelism in continuous variation, Sex-linked genes, Maternal effects - estimation of their contribution, Stability models.

Unit V

Correlations between relatives, Heritability, Repeatability and Genetic correlation. Response due to selection, Selection index and its applications in plants and animals' improvement programmes, Correlated response to selection.

Unit VI

Restricted selection index. Variance component approach and linear regression approach for the analysis of GE interactions. Measurement of stability and adaptability for genotypes. Line X tester Analysis- Concepts of general and specific combining ability. Diallel and partial diallel crosses - construction and analysis.

VI. **Practical**

- Test for the single factor segregation ratios, homogeneity of the families with regard to single factor segregation;
- Detection and estimation of linkage parameter by different procedures;
- Estimation of genotypic and gene frequency from a given data.
- Hardy-Weinberg law;
- Estimation of changes in gene frequency due to systematic forces, inbreeding coefficient, genetic components of variation, heritability and repeatability coefficient, genetic correlation coefficient;

- Examination of effect of linkage, epistasis and inbreeding on mean and variance of metric traits;
- Mating designs;
- Construction of selection index including phenotypic index, restricted selection index. Correlated response to selection.
- Problem based on various stability models and Line X tester Analysis

VII. Suggested Reading

- Agarwal BL and Agarwal SP. 2007. *Statistical Analysis of Quantitative Genetics*. New Age International Publisher.
- Bailey NTJ. 1961. *The Mathematical Theory of Genetic Linkage*.Clarendon Press.
- Balding DJ, Bishop M and Cannings C. 2001. *Hand Book of Statistical Genetics*. John Wiley.
- Crow JF and Kimura M. 1970. *An Introduction of Population Genetics Theory*. Harper and Row.
- Dahlberg G. 1948. *Mathematical Methods for Population Genetics*. Inter Science Publ.
- East EM and Jones DF. 1919. *Inbreeding and Outbreeding*.
- Lippincott JB & Co. Ewens WJ. 1979. *Mathematics of Population Genetics*. Springer.
- Falconer DS. 1985. *Introduction to Quantitative Genetics*. ELBL.
- Fisher RA. 1949. *The Theory of Inbreeding*. Oliver & Boyd.
- Fisher RA. 1950. *Statistical Methods for Research Workers*. *Oliver*& Boyd.
- Fisher RA. 1958. *The Genetical Theory of Natural Selection*. *Dover* Publ.
- Kempthorne O. 1957. *An Introduction to Genetic Statistics*. The Iowa State Univ. Press.
- Lerner IM. 1950. *Population Genetics and Animal Improvement*.Cambridge Univ. Press.
- Lerner IM. 1954. *Genetic Homeostasis*. Oliver & Boyd.
- Lerner IM. 1958. *The Genetic Theory of Selection*. John Wiley.
- Li CC. 1982. *Population Genetics*. The University of Chicago Press.
- K & Jinks JL. 1977. *Introduction to Biometrical Genetics*.Chapman & Hall.
- Mather K and Jinks JL. 1982. *Biometrical Genetics*. Chapman & Hall.
- Mather K. 1949. *Biometrical Genetics*. Methuen.
- Mather K. 1951. *The Measurement of Linkage in Heredity*.
- Methuen. N. P. 1990. *Statistical Genetics*. Wiley Eastern.

I. Course Title : Statistical Quality Control

II. Course Code : STAT 566

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for exposing the students to the concepts of Statistical Quality Control and their applications in agribusiness and agro- processing industries. This course would enable the students to have an idea about the statistical techniques used in quality control. Students who do not have sufficient background of Statistical Methods.

V. **Theory**

Unit I

Introduction to Statistical Quality Control; Control Charts for Variables – Mean, Standard deviation and Range charts; Statistical basis; Rational subgroups.

Unit II

Control charts for attributes- 'np', 'p' and 'c' charts.

Unit III

Fundamental concepts of acceptance, sampling plans, single, double and sequential sampling plans for attributes inspection.

Unit IV

Sampling inspection tables for selection of single and double sampling plans.

VI. **Suggested Reading**

- Cowden D.J. 1957. *Statistical Methods in Quality Control*. Prentice Hall of India.
- Dodge H.F. and Romig H.G. 1959. *Sampling Inspection Tables*. John Wiley.
- Duncan A.J. 1986. *Quality Control and Industrial Statistics*. 5th Ed. Irwin Book Co.
- Grant E.L. and Leavenworth R.S. 1996. *Statistical Quality Control*. 7th Ed. McGraw Hill.
- Montgomery D.C. 2008. *Introduction to Statistical Quality Control*. 6th Ed. John Wiley.
- Wetherhil G.B. 1977. *Sampling Inspection and Quality Control*. Halsted Press.

I. **Course Title : Optimization Techniques**

II. **Course Code : STAT 567**

III. **Credit Hours : 1+1**

IV. **Aim of the course**

This course is meant for exposing the students to the mathematical details of the technique's optimization techniques. They will be taught numerical methods of optimization, linear programming techniques, nonlinear programming and multiple objective programming. Students will also be exposed to practical applications of these techniques.

V. **Theory**

Unit I

Classification of optimization problems, Classical optimization techniques: single variable optimization, multivariable optimization techniques with no constraints, multivariable optimization techniques with equality constraints, multivariable optimization techniques with inequality constraints.

Unit II

Linear programming: simplex method, duality, sensitivity analysis, Karmarkar's method, transportation problem.

Unit III

Nonlinear programming Unconstrained optimization techniques: direct search methods such as random search, grid search, Hooke and Jeeves' method, Powel's method. Descent methods such as gradient method, steepest descent method, conjugate gradient method, Newton's method, Marquardt method.

Unit IV

Quadratic programming, integer linear programming, integer nonlinear programming, geometric programming, dynamic programming, stochastic programming, multi objective optimization, optimal control theory, genetic algorithms, simulated annealing, neural network based optimization,

VI. **Practical**

- Problems based on classical optimization techniques, optimization techniques with constraints, minimization problems using numerical methods.
- Linear programming (LP) problems through graphical method, simplex method, simplex two-phase method, primal and dual method.
- Sensitivity analysis for LP problem, LP problem using Karmarkar's method.
- Problems based on Quadratic programming, integer programming, dynamic programming, stochastic programming.
- Problems based on Pontryagin's maximum principle.
- Problems based on multi objective optimization.

VII. **Suggested Reading**

- Antunes C.H., Alves, M.J., Climaco J. 2016. *Multi objective Linear and Integer Programming* (EURO Advanced Tutorials on Operational Research)
- Nocedal, J. and Wright, S.J. 1999. *Numerical Optimization*. Springer.
- Rao, S.S. 2007. *Engineering Optimization: Theory and Practice*. New Age International Publishers.
- Rustagi, J.S. 1994. *Optimization Techniques in Statistics*. Academic Press.
- Taha, H.A. 2007. *Operations Research: Introduction with CD*. Pearson Education.
- Xu, H, Teo, K.L. Zhang Y. 2016. *Optimization and Control Techniques and Applications* (Springer Proceedings in Mathematics & Statistics)
- Zeleny, M. 1974. *Linear Multi objective Programming*. Springer.

I. **Course Title : Multivariate Analysis**

II. **Course Code : STAT 571**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

This course lays the foundation of Multivariate data analysis. Most of the data sets in agricultural sciences are multivariate in nature. The exposure provided to multivariate data structure, multinomial and multivariate normal distribution, estimation and testing of parameters, various data reduction methods would help the students in having a better understanding of agricultural research data, its presentation and analysis.

V. Theory

Unit I

Concept of random vector, its expectation and Variance-Covariance matrix. Marginal and joint distributions. Conditional distributions and Independence of random vectors. Multinomial distribution. Multivariate Normal distribution, marginal and conditional distributions. Sample mean vector and its distribution. Maximum likelihood estimates of mean vector and dispersion matrix tests of hypothesis about mean vector.

Unit II

Wishart distribution and its simple properties. Hotelling's T^2 and Mahalanobis D^2 statistics. Null distribution of Hotelling's T^2. Rao's U statistics and its distribution. Wilks' criterion and its properties. Concepts of discriminant analysis, computation of linear discriminant function, classification between *k* (2) multivariate normal populations based on LDF and Mahalanobis D^2.

Unit III

Principal Component Analysis, factor analysis. Canonical variables and canonical correlations. Cluster analysis: similarities and dissimilarities of qualitative and quantitative characteristics, Hierarchical clustering. Single, Complete and Average linkage methods. K-means cluster analysis.

Unit IV

Path analysis and computation of path coefficients, introduction to multidimensional scaling, some theoretical results, similarities, metric and non-metric scaling methods.

VI. Practical

- Maximum likelihood estimates of mean-vector and dispersion matrix;
- Testing of hypothesis on mean vectors of multivariate normal populations;
- Cluster analysis, Discriminant function, Canonical correlation, Principal component analysis, Factor analysis;
- Multivariate analysis of variance and covariance, multidimensional scaling.

VIII. Suggested Reading

- Abdelmonem A, Virginia AC and Susanne M. 2004. *Computer Aided Multivariate Analysis*. Chapman & Hall/CRC.
- Anderson TW. 1984. *An Introduction to Multivariate Statistical Analysis*. 2nd Ed. John Wiley.
- Arnold SF. 1981. *The Theory of Linear Models and Multivariate Analysis*. John Wiley.
- Giri NC. 1977. *Multivariate Statistical Inference*. Academic Press. Johnson RA and Wichern DW. 1988. *Applied Multivariate Statistical Analysis*. Prentice Hall.
- Kshirsagar AM. 1972. *Multivariate Analysis*. Marcel Dekker.
- Muirhead RJ. 1982. *Aspects of Multivariate Statistical Theory*. John Wiley. Muirhead, RJ. (2005) *Aspects of Multivariate Statistical Theory*.

2nd Ed. John Wiley.

- Rao CR. 1973. *Linear Statistical Inference and its Applications*. 2nd Ed. John Wiley.
- Rencher AC. 2012. *Methods of Multivariate Analysis*. 3rd Ed. John Wiley.
- Srivastava MS and Khatri CG. 1979. *An Introduction to Multivariate Statistics*. North Holland.

I. **Course Title : Regression Analysis**

II. **Course Code : STAT 572**

III. **Credit Hours : 1+1**

IV. **Aim of the course**

This course is meant to prepare the students in linear and non-linear regression methods useful for statistical data analysis. They would also be provided a mathematical foundation behind these techniques and their applications in agricultural data.

V. **Theory**

Unit I

Simple and Multiple linear regressions: Least squares fit, Properties and examples. Polynomial regression: Use of orthogonal polynomials.

Unit II

Assumptions of regression; diagnostics and transformations; residual analysis ~ Studentized residuals, applications of residuals in detecting outliers, identification of influential observations. Lack of fit, Pure error. Test of normality, test of linearity, Testing homoscedasticity and normality of errors, Durbin-Watson test. Test of goodness of fit for the model evaluation and validation. Concept of multi-collinearity.

Unit III

Weighted least squares method: Properties, and examples. Box-Cox family of transformations. Use of dummy variables, Over fitting and under fitting of model, Selection of variables: Forward selection, Backward elimination. Stepwise and Stagewise regressions.

Unit IV

Introduction to non-linear models as semi log and double logarithmic models, binary logistic and multinomial logistic models, nonlinear estimation: Least squares for nonlinear models.

VI. **Practical**

- Multiple regression fitting with three and four independent variables;
- Estimation of residuals, their applications in outlier detection, distribution of residuals;
- Test of homoscedasticity, and normality, Box-Cox transformation;
- Restricted estimation of parameters in the model, hypothesis testing, Step wise regression analysis;
- Least median of squares norm, Orthogonal polynomial fitting.

- Non-linear models including binary logistic and multinomial logistic models.

VII. Suggested Reading

- Barnett V and Lewis T. 1984. *Outliers in Statistical Data*. John Wiley.
- Belsley DA, Kuh E and Welsch RE. 2004. *Regression Diagnostics-Identifying Influential Data and Sources of Collinearity*. John Wiley.
- Chatterjee S and Hadi AS. 2013. *Regression Analysis* by *Example*. A John Wiley & sons Publication.
- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- McCullagh P and Nelder JA. 1999. *Generalized Linear Models*. 2nd Ed. *Chapman* & Hall.
- Montgomery DC, Peck EA and Vining GG. 2003. *Introduction to Linear Regression Analysis*. 3rd Ed. John Wiley.
- Rao CR. 1973. *Linear Statistical Inference and its Applications*. 2nd *Ed*. John Wiley.

I. Course Title : Statistical Computing

II. Course Code : STAT 573

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for exposing the students in the concepts of computational techniques. Various statistical packages would be used for teaching the concepts of computational techniques.

V. Theory

Unit I

Introduction to statistical packages and computing: data types and structures, Use of Software packages like, SAS, SPSS or "R: The R Project for Statistical Computing". Data analysis principles and practice, Summarization and tabulation of data, Exploratory data analysis; Graphical representation of data. Statistical Distributions: Fitting and testing the goodness of fit of discrete and continuous probability distributions;

Unit II

ANOVA, regression and categorical data methods; model formulation, fitting, diagnostics and validation; Matrix computations in linear models. Analysis of discrete data. Multiple comparisons, Contrast analysis.

Unit III

Numerical linear algebra, numerical optimization, graphical techniques, numerical approximations, Time Series Analysis.

Unit IV

Analysis of mixed models; Estimation of variance components, Analysis of Covariance, Fitting of non-linear model, Discriminant function; Principal component analysis. techniques in the analysis of survival data and longitudinal studies, Approaches to handling missing data, and meta-analysis

VI. Practical

- Data management, Graphical representation of data, Descriptive statistics;
- General linear models ~ fitting and analysis of residuals, outlier detection;
- Fitting and testing the goodness of fit of probability distributions;
- Testing the hypothesis for one sample *t*-test, two sample *t*-test, paired *t*-test, test for large samples - Chi-squares test, F test, One-way analysis of variance, contrast and its testing, pairwise comparisons;
- Mixed effect models, estimation of variance components;
- Categorical data analysis, dissimilarity measures, similarity measures;
- Analysis of discrete data, analysis of binary data;
- Numerical algorithms;
- Spatial modeling, cohort studies;
- Clinical trials, analysis of survival data;
- Handling missing data. Analysis of time series data - fitting of ARIMA models.

VII. Suggested Reading

- Agresti A. 2013. *Categorical Data Analysis*. 3rd Ed. John Wiley.
- Everitt BS and Dunn G. 1991. *Advanced Multivariate Data Analysis*. 2nd Ed. Arnold.
- Geisser S. 1993. *Predictive Inference: An Introduction*. Chapman & Hall.
- Gelman A & Hill J. 2006. *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge Univ. Press.
- Gentle JE, Härdle W and Mori Y. 2012. *Handbook of Computational Statistics – Concepts and Methods*. 2nd Ed. Springer.
- Han J and Kamber M. 2000. *Data Mining: Concepts and Techniques*. Morgan.
- Hastie T, Tibshirani R and Friedman R. 2001. *The Elements of Statistical Learning: Data Mining, Inference and Prediction*. Springer.
- Kennedy WJ & Gentle JE. 1980. *Statistical Computing*. Marcel Dekker.
- Miller RG Jr. 1986. *Beyond ANOVA, Basics of Applied Statistics*. John Wiley.
- Rajaraman V. 1993. *Computer Oriented Numerical Methods*. Prentice-Hall.
- Ross S. 2000. *Introduction to Probability Models*. Academic Press.
- Ryan BF and Joiner BL. 1994. *MINITAB Handbook.* 3rd Ed. Duxbury Press.
- Simonoff JS. 1996. *Smoothing Methods in Statistics*. Springer.
- Singh, AK. 2016. *Practical R-Book by Examples for Agricultural Statistics*. Deptt. Of Ag. Statistics, IGKV. Raipur
- Snell EJ. 1987. *Applied Statistics: A Handbook of BMDP Analyses*. Chapman & Hall.
- Thisted RA. 1988. *Elements of Statistical Computing*. Chapman & Hall.
- Venables WN and Ripley BD. 1999. *Modern Applied Statistics With S-Plus*. 3rd Ed. Springer.
- http: //www.r-project.org/
- http: //www.stat.sc.edu/~grego/courses/stat706/.
- Design Resources Server: www.drs.icar.gov.in.

I. **Course Title** : **Time Series Analysis**

II. **Course Code** : **STAT 574**

III. **Credit Hours** : **1+1**

IV. **Aim of the course**

This course is meant to teach the students the concepts involved in time series data. They would also be exposed to components of time series, stationary models and forecasting/ projecting the future scenarios based on time series data. It would also help them in understanding the concepts involved in time series data presentation, analysis and interpretation.

V. **Theory**

Unit I

Components of a time-series. Autocorrelation and Partial autocorrelation functions, Correlogram and periodogram analysis.

Unit II

Linear stationary models: Autoregressive, moving average and Mixed processes. Linear non-stationary models: Autoregressive integrated moving average processes.

Unit III

Forecasting: Minimum mean square forecasts and their properties, calculating and updating forecasts. ARIMA models, Autoregressive Conditional Heteroscedastic (ARCH) and Generalized Auto Regressive Conditional Heteroscedastic (GARCH)models

Unit IV

Model identification: Objectives, Techniques, and Initial estimates. Model estimation: Likelihood function, Sum of squares function, Least squares estimates. Seasonal models. Intervention analysis models and Outlier detection.

VI. **Practical**

Time series analysis, autocorrelations, correlogram and periodogram; Linear stationary model; Linear non-stationary model; Model identification and model estimation; Intervention analysis and outlier detection.

VII. **Suggested Reading**

- Box GEP, Jenkins GM and Reinsel GC. 2007. *Time Series Analysis: Forecasting and Control*. 3rd Ed. Pearson Edu.
- Brockwell PJ and Davis RA. 2002. *Introduction to Time Series and Forecasting*. 2nd Ed. Springer.
- Chatterjee S, Hadi A and Price B.1999. *Regression* Analysis by Examples.John Wiley.
- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Jenkins, GM, Reinsel, GC, Greta M. L, George E.P.B. 2015. *Time Series Analysis: Forecasting and Control,* Wiley Series in Probability and Statistics
- Johnston J. 1984. *Econometric Methods*. McGraw Hill.
- Judge GG, Hill RC, Griffiths WE, Lutkepohl H and Lee TC. 1988. *Introduction*

to the Theory and Practice of Econometrics. 2nd Ed. John Wiley.

- Montgomery DC and Johnson LA. 1976. *Forecasting and Time Series Analysis*. McGraw Hill.
- Montgomery DC, Jennings CA and Kulahci M. 2015. *Introduction to Time Series Analysis and Forecasting*, Wiley Series in Probability and Statistics
- Shumway RH and Stoffer DS. 2006. *Time Series Analysis and its Applications: With R Examples*. 2nd Ed. Springer.

I. Course Title : Demography

II. Course Code : STAT 575

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for training the students in measures of demographic indices, estimation procedures of demographic parameters. Students would also be exposed to population projection techniques and principle involved in bioassays.

V. Theory

Unit I

Introduction to vital statistics, crude and standard mortality and morbidity rates, Estimation of mortality, Measures of fertility and mortality, period and cohort measures.

Unit II

Life tables and their applications, methods of construction of abridged life tables, Increment-Decrement Life Tables.

Unit III

Stationary and stable populations, Migration and immigration. Application of stable population theory to estimate vital rates, migration and its estimation. Demographic relations in Nonstable populations. Measurement of population growth, Lotka's model (deterministic) and intrinsic rate of growth, Measures of mortality and morbidity Period.

Unit IV

Principle of biological assays, parallel line and slope ratio assays, choice of doses and efficiency in assays quantal responses, probit and logit transformations, epidemiological models.

VI. Suggested Reading

- Cox DR. 1957. *Demography*. Cambridge Univ. Press.
- Charles Griffin. Fleiss JL. 1981. *Statistical Methods for Rates and Proportions*. John Wiley.
- Finney DJ. 1981. *Statistical Methods in Biological Assays*.
- Grow A, Bavel JV. 2016. *Agent-Based Modelling in Population Studies: Concepts, Methods, and Applications* (The Springer Series on Demographic Methods and Population Analysis)
- Lawless JF. 1982. *Statistical Models and Methods for Lifetime Data*. John Wiley.
- MacMahon B and Pugh TF. 1970. *Epidemiology- Principles and*

Methods.Little Brown, Boston.
- Mann NR, Schafer RE and Singpurwalla ND. 1974. *Methods for Statistical Analysis of Reliability and Life Data*. John Wiley.
- Newell C. 1988. *Methods and Models in Demography*. Guilford Publ.
- Preston S, Heuveline P and Guillot M. 2001. *Demography: Measuring and Modeling Population Processes*. Blackwell Publ.
- Rowland DT. 2004. *Demographic Methods and Concepts*. Oxford Press.
- Siegel JS and Swanson DA. 2004. *The Methods and Material ofDemography*. 2nd Ed. Elsevier.
- Woolson FR. 1987. *Statistical Methods for the Analysis of Biomedical Data*. JohnWiley.
- Yakovlev AY, Klebanov L and Gaile D. 2013. *Statistical Methods for Microarray Data Analysis: Methods and Protocols* (Methods in Molecular Biology)
-

I. **Course Title : Statistical Methods for Life Sciences**

II. **Course Code : STAT 576**

III. **Credit Hours : 2+0**

IV. **Aim of the course**

This course focuses on statistical methods for discrete data collected in public health, clinical and biological studies including survival analysis. This would enable the students to understand the principles of different statistical techniques useful in public health and clinical studies conducted.

V. **Theory**

Unit I

Proportions and counts, contingency tables, logistic regression models, Poisson regression and log-linear models, models for polytomous data and generalized linear models.

Unit II

Computing techniques, numerical methods, simulation and general implementation of biostatistical analysis techniques with emphasis on data applications. Analysis of survival time data using parametric and non-parametric models, hypothesis testing, and methods for analyzing censored (partially observed) data with covariates. Topics include marginal estimation of a survival function, estimation of a generalized multivariate linear regression model (allowing missing covariates and/or outcomes).

Unit III

Proportional Hazard model: Methods of estimation, estimation of survival functions, time-dependent covariates, estimation of a multiplicative intensity model (such as Cox proportional hazards model) and estimation of causal parameters assuming marginal structural models.

Unit IV

General theory for developing locally efficient estimators of the parameters of interest in censored data models. Rank tests with censored data. Computing techniques, numerical methods, simulation and general implementation of biostatistical analysis techniques with emphasis on data applications.

Unit V

Newton, scoring, and EM algorithms for maximization; smoothing methods; bootstrapping; trees and neural networks; clustering; isotonic regression; Markov chain Monte Carlomethods.

VI. Suggested Reading

- Biswas S. 2007. *Applied Stochastic Processes. A Biostatistical and Population Oriented Approach*. Wiley Eastern Ltd.
- Collett D. 2003. *Modeling Survival Data in Medical Research*. Chapman & Hall.
- Cox D.R. and Oakes D. 1984. *Analysis of Survival Data*. Chapman & Hall.
- Hosmer DW Jr. and Lemeshow S. 1999. *Applied Survival Analysis: Regression Modeling or Time to Event*. John Wiley.
- Klein J.P. and Moeschberger M.L. 2003. *Survival Analysis: Techniques for Censored and Truncated Data*. Springer.
- Kleinbaum D.G. and Klein M 2005. *Survival Analysis. A Self Learning Text*. Springer.
- Kleinbaum D.G. and Klein M. 2005. *Logistic Regression*. 2nd Ed. Springer.
- Lee ET. 1992. *Statistical Methods for Survival Data Analysis*.
- John Wiley and Miller RG. 1981. *Survival Analysis*. John Wiley.
- Therneau T.M. and Grambsch P.M. 2000. *Modeling Survival Data: Extending the Cox Model*.Springer.

I. Course Title : Statistical Ecology

II. Course Code : STAT 577

III. Credit hours : 2+0

IV. Aim of the course

This course is meant for exposing the students to the importance and use of statistical methods in collections of ecological data, species -abundance relations, community classification and community interpretation.

V. Theory

Unit I

Ecological data, Ecological sampling; Spatial pattern analysis: Distribution methods, Quadrant-variance methods, Distance methods.

Unit II

Species-abundance relations: Distribution models, Diversity indices; Species affinity: Niche-overlap indices, interspecific association, interspecific covariation.

Unit III

Community classification: Resemblance functions, Association analysis, Cluster analysis; Community Ordination: Polar Ordination, Principal Component Analysis, Correspondence analysis, Nonlinear ordination.

Unit IV

Community interpretation: Classification Interpretation and Ordination Interpretation.

VI. **Suggested Reading**

- Gotelli N.J. and Ellison A.M. 2004. *A Primer of Ecological Statistics*
- Pielou E.C. 1970. *An introduction to Mathematical Ecology*. John Wiley.
- Reynolds J.F. and Ludwig J.A. 1988. *Statistical Ecology: A Primer on Methods and Computing.* John Wiley.
- Young L.J., Young J.H. and Young J. 1998. *Statistical Ecology: A Population Perspective.* Kluwer.

SUPPORTING COURSES IN COMPUTER APPLICATIONS

Course Code	Course Title	Credit Hours
MCA 501	Computers-Fundamentals and Programming	2+1
MCA 502	Computer Organization and Architecture	2+0
MCA 511	Introduction to Networking and Internet Applications	1+1
MCA 512	Information Technology in Agriculture	2+0

I. **Course Title** : **Computer Fundamentals and Programming**

II. **Course Code** : **MCA 501**

III. **Credit Hours** : **2+1**

IV. **Aim of the course**

This is a course on Computer Fundamentals and Programming that aims at exposing the students to understand how computer works, analytical skills to solve problems using computers. and to write computer programs using C.

V. **Theory**

Unit I

Functional units of computer, I/O devices, primary and secondary memories. Number systems: decimal, octal, binary and hexadecimal; Representation of integers, fixed and floating point numbers, Operator precedence, character representation; ASCII, Unicode.

Unit II

Programming Fundamentals with C - Algorithm, techniques of problem solving, flowcharting, stepwise refinement; Constants and variables; Data types: integer, character, real, data types; Arithmetic expressions, assignment statements, logical expressions. Control flow

Unit III

Arrays and structures. Pointers, dynamic memory allocations

Unit IV

Program Structures – functions, subroutines

Unit V

I/O operations, Program correctness; Debugging and testing of programs.

VI. **Pratical**

- Conversion of different number types;
- Creation of flow chart, conversion of algorithm/flowchart to program;
- Mathematical operators, operator precedence;
- Sequence, control and iteration;
- Arrays and string processing;
- Matrix operations, Sorting, Pointers and File processing – Reading and writing text files.

VII. **Suggested Reading**

- Balaguruswamy E. 2019. *Programming with ANSI C*. Tata McGraw Hill.
- Gottfried B. 2017. *Programming with C, Schaum Outline Series*. Tata McGraw Hill.
- Kanetkar Y. 1999. *Let Us C*. BPB Publ.
- Malvino A.P. and Brown J.A. 2017. *Digital Computer Electronics*. Tata McGrawHill.
- Mano M.M. 1999. *Digital Logic and Computer Design*. Prentice Hall of India.

I. **Course Title** : **Computer Organization and Architecture**

II. **Course Code** : **MCA 502**

III. **Credit Hours** : **2+0**

IV. **Aim of the course**

This is a course on Computer Organization and Architecture that aims at exposing the students to understand basic knowledge of how computer works.

V. **Theory**

Unit I

Number systems; Boolean algebra - minimization of Boolean function using KarnaughMap.

Unit II

Logic Gates, Combinational circuits – multiplexer, de-multiplexer, encoder, decoder; Sequential circuits: Flip-flops, Half and Full adder, Shift register, Counters.

Unit III

Organization of CPU, Control Unit- Instruction and Execution cycle in CPU, Register Organization, The Instruction Cycle, Instruction Pipelining.

Unit IV

Memory organization - Internal memory: Semiconductor Main Memory (RAM, ROM, EPROM), Cache Memory, Advanced DRAM Organization; External Memory - Magnetic Disks, RAID, Optical Memory, Magnetic Tape.**Unit V**

Basic structure of computer hardware and system software - Addressing methods and machine programme sequencing; Input-output organizations - accessing I/O devices - direct memory access (DMA) – interrupts.

Unit VI

Introduction to microprocessors – CISC and RISC Architecture, Study of functional units of microprocessors.

VI. **Suggested Reading**

- Gear C.W. 1974. *Computer Organization and Programming*. McGraw Hill.
- Hayes J.P. 1988. *Computer Architecture and Organisation*. McGraw Hill.
- Malvino A.P and Brown J.A. 1999. *Digital Computer Electronics*. Tata McGraw Hill.
- Mano M.M. 1999. *Digital Logic and Computer Design*. Prentice Hall of India.
- Mano M.M. 2007. *Computer System Architecture*. Prentice Hall of India.
- Stallings W. 2016. *Computer Organization and Architecture: Designing for Performance*. Pearson Edu.

I. **Course Title : Introduction to Networking and Internet Applications**

II. **Course Code : MCA 511**

III. **Credit Hours : 1+1**

IV. **Aim of the course**

This is a course on Introduction to Networking and Internet Applications applications development.

V. **Theory**

Unit I

Networking fundamentals, types of networking, network topology; Introduction to File Transfer Protocol (FTP), Telnet, Simple Mail Transfer Protocol (SMTP), Internet Protocol v4 & v6. Network infrastructure and Security-switches, routers, firewall, intranet, internet, Virtual Private Network

Unit II

World Wide Web (www), working with Internet; Web pages, web sites, web servers; Web Applications.

Unit III

Hyper Text Markup Language (HTML), DHTML, web-based application development. Static websites, dynamic websites. Client-Side processing – scripting languages, Jquery. Server-Side processing ASP.NET/JSP

VI. **Practical**

- Network and mail configuration;
- Using Network Services;
- Browsing of Internet;
- Creation of web pages;
- Creation of websites using HTML and scripting languages.

VII. **Suggested Reading**

- Cox V, Wermers L and Reding E.E. 2006. *HTML Illustrated Complete*. 3rd Ed. Course Technology.
- Niederst J. 2001. *Web Design in a Nutshell*. O'Reilly Media.
- Tanenbaum A.S. 2003. Computer Networks. *Prentice* Hall of India.

I. **Course Title : Information Technology in Agriculture**

II. **Course Code : MCA 512**

III. **Credit Hours : 2+0**

IV. **Aim of the course**

This is a course on Introduction to Networking and Internet Applications that aims at exposing the students to understand analogy of computer, basic knowledge of MS Office. Also, to understand Internet and WWW, use of IT application and different IT tools in Agriculture

V. **Theory**

Unit I

Introduction to Computers, Anatomy of computer, Operating Systems, definition and types, Applications of MS Office for document creation & Editing, Data presentation, interpretation and graph creation, statistical analysis, mathematical expressions,

Unit II

Database, concepts and types, uses of DBMS in Agriculture, World Wide Web (WWW): Concepts and components, Introduction to computer programming languages, concepts and standard input/output operations. e-Agriculture, concepts and applications,

Unit III

Use of ICT in Agriculture, Computer Models for understanding plant processes. IT application for computation of water and nutrient requirement of crops, Computer- controlled devices (automated systems) for Agri-input management, Smartphone Apps in Agriculture for farm advises, market price, postharvest management etc.,

Unit IV

Geospatial technology for generating valuable agri-information. Decision support systems, concepts, components and applications in Agriculture, Agriculture Expert System, Soil Information Systems etc. for supporting Farm decisions, Preparation of contingent crop-planning using IT tools.

swSuggested Reading

- Vanitha G. 2011. *Agro-informatics*
- http://www.*agrimoon*.com
- http://www.agriinfo.in
- http://www.eagri.org
- http://www.agriglance.com
- http://agritech.tnau.ac.in

COMMON COURSES

PGS 501 LIBRARY AND INFORMATION SERVICES (0+1)

Objective

To equip the library users with skills to trace information from libraries efficiently, to apprise them of information and knowledge resources, to carry out literature survey, to formulate information search strategies, and to use modern tools (Internet, OPAC, search engines, etc.) of information search.

Practical

Introduction to library and its services; Role of libraries in education, research and technology transfer; Classification systems and organization of library; Sources of information- Primary Sources, Secondary Sources and Tertiary Sources; Intricacies of abstracting and indexing services (Science Citation Index, Biological Abstracts, Chemical Abstracts, CABI Abstracts, etc.); Tracing information from reference sources; Literature survey; Citation techniques/ Preparation of bibliography; Use of CD-ROM Databases, Online Public Access Catalogue and other computerized library services; Use of Internet including search engines and its resources; e- resources access methods.

PGS 502 TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

To equip the students/ scholars with skills to write dissertations, research papers, etc. To equip the students/ scholars with skills to communicate and articulate in English (verbal as well as writing).

Practical (Technical Writing)

- Various forms of scientific writings- theses, technical papers, reviews, manuals, etc.;
- Various parts of thesis and research communications (title page, authorship contents page, preface, introduction, review of literature, material and methods, experimental results and discussion);
- Writing of abstracts, summaries, précis, citations, etc.;
- Commonly used abbreviations in the theses and research communications;
- Illustrations, photographs and drawings with suitable captions; pagination, numbering of tables and illustrations;
- Writing of numbers and dates in scientific write-ups;
- Editing and proof-reading;
- Writing of a review article;
- Communication Skills - Grammar (Tenses, parts of speech, clauses, punctuation marks);
- Error analysis (Common errors), Concord, Collocation, Phonetic symbols and transcription;
- Accentual pattern: Weak forms in connected speech;
- Participation in group discussion;
- Facing an interview;
- Presentation of scientific papers.

Suggested Readings

1. Barnes and Noble. Robert C. (Ed.). 2005. *Spoken English: Flourish Your Language*.
2. *Chicago Manual of Style*. 14th Ed. 1996. Prentice Hall of India.

3. *Collins' Cobuild English Dictionary*. 1995.
4. Harper Collins. Gordon HM and Walter JA. 1970. *Technical Writing*. 3rd Ed.
5. Holt, Rinehart and Winston. Hornby AS. 2000. *Comp. Oxford Advanced Learner's Dictionary of Current English*. 6th Ed. Oxford University Press.
6. James HS. 1994. *Handbook for Technical Writing*. NTC Business Books.
7. Joseph G. 2000. *MLA Handbook for Writers of Research Papers*. 5th Ed. Affiliated East-West Press.
8. Mohan K. 2005. *Speaking English Effectively*. MacMillan India.
9. Richard WS. 1969. *Technical Writing*.
10. Sethi J and Dhamija PV. 2004. *Course in Phonetics and Spoken English*. 2nd Ed. Prentice Hall of India.
11. Wren PC and Martin H. 2006. *High School English Grammar and Composition*. S. Chand & Co.

PGS 503 INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE (1+0)

Objective

The main objective of this course is to equip students and stakeholders with knowledge of Intellectual Property Rights (IPR) related protection systems, their significance and use of IPR as a tool for wealth and value creation in a knowledge-based economy.

Theory

Historical perspectives and need for the introduction of Intellectual Property Right regime; TRIPs and various provisions in TRIPS Agreement; Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs; Indian Legislations for the protection of various types of Intellectual Properties; Fundamentals of patents, copyrights, geographical indications, designs and layout, trade secrets and traditional knowledge, trademarks, protection of plant varieties and farmers' rights and biodiversity protection; Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection; National Biodiversity protection initiatives; Convention on Biological Diversity; International Treaty on Plant Genetic Resources for Food and Agriculture; Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement.

Suggested Readings

1. Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
2. Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
3. *Intellectual Property Rights: Key to New Wealth Generation*. 2001. NRDC and Aesthetic Technologies.
4. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
5. Rothschild M and Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics*. CABI.
6. Saha R. (Ed.). 2006. *Intellectual Property Rights in NAM and Other*

Developing Countries: A Compendium on Law and Policies. Daya Publ. House.

The Indian Acts - Patents Act, 1970 and amendments; Design Act, 2000; Trademarks Act, 1999; The Copyright Act, 1957 and amendments; Layout Design Act, 2000; PPV and FR Act 2001, and Rules 2003; The Biological Diversity Act, 2002.

PGS 504 BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

To acquaint the students about the basics of commonly used techniques in laboratory.

Practical

- Safety measures while in Lab;
- Handling of chemical substances;
- Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes and vaccupets;
- Washing, drying and sterilization of glassware;
- Drying of solvents/ chemicals;
- Weighing and preparation of solutions of different strengths and their dilution;
- Handling techniques of solutions;
- Preparation of different agro-chemical doses in field and pot applications;
- Preparation of solutions of acids;
- Neutralisation of acid and bases;
- Preparation of buffers of different strengths and pH values;
- Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath, oilbath;
- Electric wiring and earthing;
- Preparation of media and methods of sterilization;
- Seed viability testing, testing of pollen viability;
- Tissue culture of crop plants;
- Description of flowering plants in botanical terms in relation to taxonomy.

Suggested Readings

1. Furr AK. 2000. *CRC Hand Book of Laboratory Safety*. CRC Press. mmon Academic Regulations for PG and Ph.D. Programmes. Restructured and Revised Syllabi of Post-graduate Programmes Vol. 1
2. Gabb MH and Latchem WE. 1968. *A Handbook of Laboratory Solutions*. Chemical Publ. Co.

PGS 505 - Agricultural Research, Research Ethics and Rural Development Programmes (1+0) (Agronomy, Agricultural Extension, Agricultural Economics)

Objective

To enlighten the students about the organization and functioning of agricultural research systems at national and international levels, research ethics, and rural development programmes and policies of Government.

Theory

UNIT I

History of agriculture in brief; Global agricultural research system: need, scope, opportunities; Role in promoting food security, reducing poverty and protecting the environment; National Agricultural Research Systems (NARS) and Regional Agricultural Research Institutions; Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), partnership with NARS, role as a partner in the global agricultural research system, strengthening capacities at national and regional levels; International fellowships for scientific mobility. International organizations for rural development and research.

UNIT II

Research ethics: research integrity, research safety in laboratories, welfare of animals used in research, computer ethics, standards and problems in research ethics. Research involving human participants; data management and protection; intellectual property; plagiarism; authorship – conflict of interest; peer review and publication ethics; collaborative research and data management and integrity.

UNIT III

Concept and connotations of rural development, rural development policies and strategies. Rural development programmes: Community Development Programme, Intensive Agricultural District Programme, Special group – Area Specific Programme, Integrated Rural Development Programme (IRDP) Panchayati Raj Institutions, Co-operatives, Voluntary Agencies/ Non-Governmental Organisations. Critical evaluation of rural development policies and programmes. Constraints in implementation of rural policies and programmes. Role of NABARD, commercial banks and co-operatives in rural development; National and International programmes for rural development.

Suggested Reading

- Bhalla, G. S. and Singh, G. 2001. *Indian Agriculture - Four Decades of Development*. Sage Pub.
- Pimple, K. D. 2000. Letter Commenting on the "Proposed PHS Policy on Instruction in the Responsible Conduct of Research (RCR)." Available: http: // php.indiana.edu / ~pimple/rcrpolicy.pdf
- Pimple, K. D. 2002. Six domains of research ethics: a heuristic framework for the responsible conduct of research. *Sci. Eng. Ethics* 8:191-205.
- Punia, M. S. *Manual on International Research and Research Ethics*. CCS Haryana Agricultural University, Hisar.
- Rao, B. S. V. 2007. *Rural Development Strategies and Role of Institutions - Issues, Innovations and Initiatives*. Mittal Pub.
- Singh, K. 1998. *Rural Development - Principles, Policies and Management*. Sage Pub.