P.G & Ph.D PROGRAMMES
(*FACULTY OF AGRICULTURE)*

Revised Syllabi of Post Graduate Programmes

2022

KERALA AGRICULTURAL UNIVERSITY

CONTENT

KERALA AGRICULTURAL UNIVERSITY

RESTRUCTURED AND REVISED SYLLABUS
FOR P.G. AND Ph.D. PROGRAMMES

AGRONOMY

Course Title with Credit Load for M.Sc. and Ph D in Agronomy

Course Code	Course title	Credit hours
Agron. 501*	Modern Concepts in Crop Production	3 + 0
Agron. 502*	Principles and Practices of Soil Fertility and Nutrient Management	2 + 1
Agron. 503*	Principles and Practices of Weed Management	2 + 1
Agron. 504*	Principles and Practices of Water Management	2 + 1
Agron. 505	Conservation Agriculture	1 + 1
Agron. 506	Agronomy of Major Cereals and Pulses	2 + 1
Agron. 507	Agronomy of Oilseed, Fibre and Sugar Crops	2 + 1
Agron. 508	Agronomy of Medicinal, Aromatic and Underutilized Crops	2 + 1
Agron. 509	Agronomy of Fodder and Forage crops	2 + 1
Agron. 510	Agrostology and Agro-forestry	2 + 1
Agron. 511	Cropping System and Sustainable Agriculture	2 + 0
Agron. 512	Dryland Farming and Watershed Management	2 + 1
Agron. 513	Principles and Practices of Organic Farming	2 + 1
Agron. 591	Master's Seminar	0+1
Agron. 599	Master's Research	0+30
Agron. 601**	Current Trends in Agronomy	3 + 0
Agron. 602	Recent Trends in Crop Growth and Productivity	2 + 1
Agron. 603	Irrigation Management	2 + 1
Agron. 604	Recent Trends in Weed Management	2 + 0
Agron. 605	Integrated Farming Systems for Sustainable Agriculture	2 + 0
Agron. 606	Soil Conservation and Watershed Management	2 + 1
Agron. 607	Stress Crop Production	2 + 1
Agron. 608**	Research and Publication Ethics	2 + 0
Agron. 691	Doctoral Seminar – I	0+1
Agron. 692	Doctoral Seminar – II	0+1
Agron. 699	Doctoral Research	0+75

* Compulsory for Master's Programme

** Compulsory for Ph D Programme

I.	Course title	:	**Modern Concepts in Crop Production**
II.	Course code	:	**Agron. 501**
III.	Credit hours	:	**3 + 0**
IV.	Aim of the course	:	To teach the basic concepts of soil management and crop production

Theory

Unit I

Crop growth analysis in relation to environment; geo-ecological zones of India.

Unit II

Quantitative agro-biological principles and inverse yield nitrogen law; Mitscherlich yield equation, its interpretation and applicability; Baule unit.

Unit III

Effect of lodging in cereals; physiology of grain yield in cereals; optimization of plant population and planting geometry in relation to different resources, concept of ideal plant type and crop modeling for desired crop yield.

Unit IV

Scientific principles of crop production; crop response production functions; concept of soil plant relations; yield and environmental stress, use of growth hormones and regulators for better adaptation in stressed condition.

Unit V

Integrated farming systems, organic farming, and resource conservation technology including modern concept of tillage; dry farming; determining the nutrient needs for yield potentiality of crop plants, concept of balanced nutrition and integrated nutrient management; precision agriculture. Modern crop production concepts: soil less cultivation, Aeroponics, Hydroponics, Robotics and terrace farming. use of GIS, GPS and remote sensing in modern agriculture, precision farming and protected agriculture.

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments and class discussion

Learning outcome

Basic knowledge on soil management and crop production

Suggested Reading

- Balasubramaniyan, P. and Palaniappan, SP. 2001. *Principles and Practices of Agronomy*. Agrobios.
- Fageria, N. K. 1992. *Maximizing Crop Yields*. Marcel Dekker.
- Havlin, J. L., Beaton, J. D., Tisdale, S. L. and Nelson, W. L. 2006. *Soil Fertility and Fertilizers.* 7th Ed. Prentice Hall.
- Paroda, R. S. 2003. *Sustaining Our Food Security*. Konark Pub

- Reddy, S. R. 2000. *Principles of Crop Production*. Kalyani Pub
- Sankaran, S. and Mudaliar, T. V. S. 1997. *Principles of Agronomy*. The Bangalore Printing and Pub
- Singh, S. S. 2006. *Principles and Practices of Agronomy*. Kalyani.
- Alvin, P.T. and Kozlowski, T. T. (eds). 1976. *Ecophysiology of Tropical Crops*. Academia Pul., New York.
- Gardner, P. P., Pearce, G. R., and Mitchell, R. L. 1985. *Physiology of Crop Plants*. Scientific Pub. Jodhpur.
- Lal, R. 1989. *Conservation Tillage for Sustainable Agriculture: Tropics versus Temperate Environments. Advances in Agronomy* 42: 85-197.
- Wilsie, C. P. 1961. *Crop Adaptation and Distribution*. Euresia Pub., New Delhi.

I.	Course title	:	**Principles and Practices of Soil Fertility and Nutrient Management**
II.	Course code	:	**Agron. 502**
III.	Credit hours	:	**2 + 1**
IV.	Aim of the course	:	To impart knowledge about fertilizers and manures as sources of plant nutrients and apparise about the integrated approach of plant nutrition and sustainability of soil fertility.

Theory

Unit I

Soil fertility and productivity - factors affecting; features of good soil management; problems of supply and availability of nutrients; relation between nutrient supply and crop growth; organic farming - basic concepts and definitions.

Unit II

Criteria of essentiality of nutrients; Essential plant nutrients – their functions,nutrient deficiency symptoms; transformation and dynamics of major plant nutrients.

Unit III

Preparation and use of farmyard manure, compost, green manures, vermicompost, biofertilizers and other organic concentrates their composition, availability and crop responses; recycling of organic wastes and residue management. Soil less cultivation.

Unit IV

Commercial fertilizers; composition, relative fertilizer value and cost; crop response to different nutrients, residual effects and fertilizer use efficiency; agronomic and physiological, fertilizer mixtures and grades; methods of increasing fertilizer use efficiency; nutrient interactions.

Unit V

Time and methods of manures and fertilizers application; foliar application and its concept; relative performance of organic and inorganic nutrients; Fertigation – definition, importance, components/ equipments, nutrient use efficiency and economics
- fertigation schedule for major crops; economics of fertilizer use; integrated nutrient management.

Practical

- Determination of soil pH and soil EC
- Determination of soil organic C
- Determination of available N, P, K and S of soil
- Determination of total N, P, K and S of soil
- Determination of total N, P, K, S in plant
- Computation of optimum and economic yield
- Field visit to familiarise with the components and working of fertigation unit

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments and class discussion

Learning outcome

Basic knowledge on soil fertility and management.

Suggested Reading

- Brady, N. C. and Weil, R. R. 2002. *The Nature and Properties of Soils.* 13th Ed. Pearson Edu.
- Fageria, N. K., Baligar, V. C., and Jones, C. A. 1991. *Growth and Mineral Nutrition of Field Crops.* Marcel Dekker.
- Havlin, J. L., Beaton, J. D., Tisdale, S. L., and Nelson, W. L. 2006. *Soil Fertility and Fertilizers.* 7th Ed. Prentice Hall.
- Prasad, R. and Power, J. F. 1997. *Soil Fertility Management for Sustainable Agriculture*. CRC Press.
- Yawalkar, K. S., Agrawal, J. P., and Bokde, S. 2000. *Manures and Fertilizers*. Agri-Horti Pub

I.	Course title	:	**Principles and Practices of Weed Management**
II.	Course code	:	**Agron. 503**
III.	Credit hours	:	**2 + 1**
IV.	Aim of the course	:	To familiarize the students about weeds, herbicides and methods of weed management

Theory

Unit I

Weed biology, ecology and classification, crop-weed competition including allelopathy; principles of weed control, classification of weed management techniques; weed indices, weed shift in different eco-systems

Unit II

Herbicides introduction and history of their development; classification based on chemical, physiological, methods of application and selectivity; mode and mechanism of action of herbicides.

Unit III

Herbicide structure - activity relationship; factors affecting the efficiencyof herbicides; herbicide formulations, herbicide mixtures, sequential applicationof herbicides, rotation; weed control through use of nano-herbicides and bio-herbicides, myco-herbicides bio-agents, and allelochemicals; movement of herbicides in soil and plant, Degradation of herbicides in soil and plants; herbicide resistance, residue, persistence and management; development of herbicide resistance in weeds and crops and their management, herbicide combination and rotation.

Unit IV

Weed management in major crops and cropping systems; alien, invasive and parasitic weeds and their management; weed shifts in cropping systems; aquatic and perennialweed control; weed control in non-crop area.

Unit V

Integrated weed management; recent development in weed management- robotics, use of drones and aeroplanes, weed management in organic systems, etc., cost: benefit analysis of weed management.

Practical

- Identification of important weeds of different crops
- Preparation of a weed herbarium
- Weed survey in crops and cropping systems
- Crop-weed competition studies
- Weed indices calculation and interpretation with data
- Preparation of spray solutions of herbicides for high and low-volume sprayers
- Use of various types of spray pumps and nozzles and calculation of swath width
- Economics of weed control
- Herbicide residue analysis in plant and soil
- Bioassay of herbicide residues
- Calculation of herbicide requirement

Teaching methods / activities

Classroom teaching with AV aids, group discussion, field visit to identify weeds

Learning outcome

Basic knowledge on weed identification and control for crop production.

Suggested Reading

- Böger, P., Wakabayashi, Ko, Hirai, K. (Eds.). 2002. *Herbicide Classes in Development*. *Mode of Action*, *Targets*, *Genetic Engineering*, *Chemistry*. Springer.
- Chauhan, B. and Mahajan, G. 2014. *Recent Advances in Weed Management*. Springer.
- Das, T. K. 2008. *Weed Science: Basics and Applications*, Jain Brothers (New Delhi).
- Fennimore, S. A. and Bell, C. 2014. *Principles of Weed Control*, 4th Ed, California Weed Sci. Soc.
- Gupta, O. P. 2007. *Weed Management*: *Principles and Practices*, 2nd Ed.
- Jugulan, M. (Ed). 2017. *Biology, Physiology and Molecular Biology of Weeds*. CRC Press
- Monaco, T.J., Weller, S. C., and Ashton, F. M. 2014. *Weed Science Principles and Practices*, Wiley
- Powles, S. B. and Shaner, D. L. 2001. *Herbicide Resistance and World Grains*. CRC Press.
- Walia, U. S. 2006. *Weed Management*, Kalyani Publishers.
- Zimdahl, R. L. (Ed). 2018. *Integrated Weed Management for Sustainable Agriculture, B. D. Sci. Pub.*

I.	Course title	:	**Principles and Practices of Water Management**
II.	Course code	:	**Agron. 504**
III.	Credit hours	:	**2 + 1**
IV.	Aim of the course	:	To teach the principles of water management and practices to enhance the water productivity

Theory

Unit I

Water and its role in plants; Irrigation: Definition and objectives, water resources and irrigation development in India and Kerala, major irrigation projects, extent of area and crops irrigated in India and in different states.

Unit II

Field water cycle, water movement in soil and plants; transpiration; soil-water- plant relationships; water absorption by plants; plant response to water stress, crop plant adaptation to moisture stress condition. Water availability and its relationship with nutrient availability and losses.

Unit III

Soil, plant and meteorological factors determining water needs of crops, scheduling, depth and methods of irrigation; micro irrigation systems; deficit irrigation; fertigation; management of water in controlled environments and polyhouses. Irrigation efficiency and water use efficiency.

Unit IV

Water management of crop and cropping system, Quality of irrigation water and management of saline water for irrigation, Crop water requirement- estimation of ET and effective rainfall; Water management of the major crops and cropping systems. Automated irrigation system.

Unit V

Excess soil water and plant growth; water management in problem soils, drainage requirement of crops and methods of field drainage, their layout and spacing; rain water management and its utilization for crop production.

Unit VI

Quality of irrigation water and management of saline water for irrigation, water management in problem soils

Unit VII

Soil moisture conservation, water harvesting, rain water management and its utilization for crop production.

Unit VIII

Hydroponics.

Unit IX

Water management of crops under climate change scenario.

Practical

- Determination of field capacity by field method
- Determination of permanent wilting point by sunflower pot culture technique
- Determination of field capacity and permanent wilting point by Pressure PlateApparatus
- Determination of Hygroscopic Coefficient
- Determination of maximum water holding capacity of soil
- Measurement of matric potential using gauge and mercury type tensiometer
- Determination of soil-moisture characteristic curves
- Determination of saturated hydraulic conductivity by constant and falling headmethod
- Determination of hydraulic conductivity of saturated soil below the water table byauger hole method
- Measurement of soil water diffusivity
- Estimation of unsaturated hydraulic conductivity
- Estimation of upward flux of water using tensiometer and from depth to ground watertable

- Determination of irrigation requirement of crops (calculations)
- Determination of effective rainfall (calculations)
- Determination of ET of crops by soil moisture depletion method
- Determinationof water requirement of crops
- Measurement of irrigation water by volume and velocity-area method
- Measurement of irrigation water by measuring devices and calculation of irrigationefficiency
- Determination of infiltration rate by double ring infiltrometer

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments and field visit.

Learning outcome

Basic knowledge on water management for optimization of crop yield.

Suggested Reading

- Majumdar, D. K. 2014. *Irrigation Water Management: Principles and Practice*. PHL Learning private publishers
- Mukund, J. 2013. *A Text Book of Irrigation and Water Management Hardcover*, Kalyani publishers
- Lenka, D. 1999. *Irrigation and Drainage*. Kalyani.
- Michael, A. M. 1978. *Irrigation: Theory and Practice*. Vikas Pub
- Paliwal, K. V. 1972. *Irrigation with Saline Water*. IARI Monograph, New Delhi.
- Panda, S. C. 2003. *Principles and Practices of Water Management*. Agrobios.
- Prihar , S. S. and Sandhu, B. S. 1987. *Irrigation of Food Crops - Principles and Practices*. ICAR.
- Reddy, S. R. 2000. *Principles of Crop Production*. Kalyani.
- Singh, P. and Maliwal, P. L. 2005. *Technologies for Food Security and Sustainable Agriculture*. Agrotech Pub

I.	Course title	:	**Conservation Agriculture**
II.	Course code	:	**Agron. 505**
III.	Credit hours	:	**1 + 1**
IV.	Aim of the course	:	To impart knowledge of conservation of agriculture for economic development

Theory

Unit I

Conventional and conservation agriculture systems, sustainability concerns, conservation agriculture: Historical background and present concept, global experiences, present status in India.

Unit II

Nutrient management in CA, water management, weed management, energy use, insect-pest and disease management, farm machinery, crop residue management, cover crop management.

Unit III

Climate change mitigation and CA, C-sequestration, soil health management, soil microbes and CA.

Unit IV

CA in agroforestry systems, rainfed / dryland regions

Unit V

Economic considerations in CA, adoption and constraints, prospects of CA in future agriculture

Practicals

- Study of experiments/long-term experiments on CA,
- Evaluation of soil health parameters,
- Estimation of C-sequestration,
- Machinery calibration for sowing different crops, weed seedbank estimation under CA, energy requirements, economic analysis of CA.

Teaching methods / activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on the knowledge of various types of conservation agriculture.

Suggested Reading

- Arakeri, H. R. and Roy, D. 1984. *Principles of Soil Conservation and Water Management*. Oxfordand IBH.
- Bisht, J. K., Meena, V. S., Mishra, P. K., and Pattanayak, A. 2016. *Conservation Agriculture - An Approach to Combat Climate Change in Indian Himalaya*. Publisher: Springer Nature. Doi: 10/1007/978-981-10-2558-7.
- Dhruvanarayana, V. V. 1993. *Soil and Water Conservation Research in India*. ICAR.
- FAO [Food and Agriculture Organization of the United Nations]. 2004. *Soil and Water Conservation in Semi-Arid Areas*. *Soils Bull.*, Paper 57.
- Gracia-Torres, L., Benites, J., Martinez-Vilela, A., and Holgado-Cabera, A. 2003. Conservation Agriculture- Environment, Farmers Experiences, Innovations, Socio-economy, Policy. Food and Agriculture Organization, Rome.
- Muhammad, F. and Kamdambot, H. M. S. 2014. *Conservation Agriculture*. Springer Cham Heidelberg, New York Dordrecht London. Doi: 10.1007/978- 3-319-11620-4.

- Reddy, T. Y. and Reddy, G. H. S. 1992. *Principles of Agronomy*. Kalyani.

I.	Course title	:	**Agronomy of Major Cereals and Pulses**
II.	Course code	:	**Agron. 506**
III.	Credit hours	:	**2 + 1**
IV.	Aim of the course	:	To impart knowledge about crop husbandry of cereals and pulses

Theory

Origin and history, area and production, classification, improved varieties, adaptability, climate, soil, water and cultural requirements, nutrition, quality components, handling and processing of the produce for maximum production of:

Unit I : *Rabi* cereals.

Unit II : *Kharif* cereals.

Unit III : *Rabi* pulses.

Unit IV : *Kharif* pulses.

Practical

- Phenological studies at different growth stages of crop
- Estimation of crop yield on the basis of yield attributes
- Formulation of cropping schemes for various farm sizes and calculation of cropping and rotational intensities
- Working out growth indices (CGR, RGR, NAR, LAI, LAD, LAR, LWR, SLA, SLW etc)
- Assessment of land use and yield advantage (Rotational intensity, Cropping intensity, Diversity Index, Sustainable Yield Index, Crop Equivalent Yield, Land Equivalent ration, Aggressiveness, Relative Crowding Coefficient, Competition Ratio and ATER etc)
- Estimation of protein content in pulses
- Planning and layout of field experiments
- Judging of physiological maturity in different crops
- Intercultural operations in different crops
- Determination of cost of cultivation of different crops
- Working out harvest index of various crops
- Study of seed production techniques in selected crops
- Visit of field experiments on cultural, fertilizer, weed control and water management aspects

- Visit to nearby areas for identification of constraints in crop production

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments and class discussion.

Learning outcome

Basic knowledge on cereals and pulse growing in the State and country.

Suggested Reading

- Das, N. R. 2007. *Introduction to Crops of India*. Scientific Pub
- Hunsigi, G. and Krishna, K. R. 1998. *Science of Field Crop Production*. Oxford and IBH.
- Jeswani, L. M. and Baldev, B. 1997. *Advances in Pulse Production Technology*.ICAR.
- Khare, D. and Bhale, M. S. 2000. *Seed Technology*. Scientific Pub
- Kumar, R. and Singh, N. P. 2003. *Maize Production in India: Golden Grain in Transition*.IARI, New Delhi.
- Pal, M., Deka, J., and Rai, R. K. 1996. *Fundamentals of Cereal Crop Production*.Tata McGraw Hill.
- Prasad, R. 2002. *Text Book of Field Crop Production*. ICAR.
- Singh, C., Singh, P., and Singh, R. 2003. *Modern Techniques of Raising Field Crops*. Oxford andIBH.
- Singh, S. S. 1998. *Crop Management*. Kalyani.
- Yadav, D. S. 1992. *Pulse Crops*. Kalyani.

I.	Course title	:	**Agronomy of Oilseed, Fibre and Sugar Crops**
II.	Course code	:	**Agron. 507**
III.	Credit hours	:	**2 + 1**
IV.	Aim of the course	:	To impart knowledge about crop husbandry of oilseeds, fibre crops and sugar yielding crops.

Theory

Origin and history, area and production, classification, improved varieties, adaptability, climate, soil, water and cultural requirements, nutrition, quality component, handling and processing of the produce for maimum production of:

Unit I

Rabi oilseeds - rapeseed and mustard, linseed and niger.

Unit II

Kharif oilseeds - groundnut, sesame, castor, sunflower, soybean and safflower.

Unit III

Fiber crops - cotton, jute, ramie and mesta.

Unit IV

Sugar crops - sugar-beet and sugarcane.

Practical

- Planning and layout of field experiments
- Cutting of sugarcane setts, its treatment and methods of sowing, tying and propping of sugarcane
- Determination of cane maturity and calculation on purity percentage, recovery percentage and sucrose content in cane juice phenological studies at different growth stages of crop
- Intercultural operations in different crops
- Cotton seed treatment
- Working out growth indices (CGR, RGR, NAR, LAI, LAD, LAR, LWR, SLA, SLW)
- Assessment of land use and yield advantage (Rotational intensity, Cropping intensity, Diversity Index, Sustainable Yield Index Crop Equivalent Yield, Land Equivalent ration, Aggressiveness, Relative Crowding Coefficient, Competition Ratio and ATER
- Judging of physiological maturity in different crops and working out harvest index
- Working out cost of cultivation of different crops
- Estimation of crop yield on the basis of yield attributes
- Formulation of cropping schemes for various farm sizes and calculation of croppingand rotational intensities
- Determination of oil content in oilseeds and computation of oil yield
- Estimation of quality of fibre of different fibre crops
- Study of seed production techniques in various crops
- Visit of field experiments on cultural, fertilizer, weed control and water management aspects
- Visit to nearby villages for identification of constraints in crop production

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments and class discussion

Learning outcome

Basic knowledge on production of oilseed, sugar and fibre crops.

Suggested Reading

- Das, N. R. 2007. *Introduction to Crops of India*. Scientific Pub
- Das, P. C. 1997. *Oilseed Crops of India*. Kalyani.

- Lakshmikantam, N. 1983. *Technology in Sugarcane Growing*. 2nd Ed. Oxford and IBH.
- Prasad. R. 2002. *Text Book of Field Crop Production*. ICAR.
- Singh, C, Singh, P., and Singh, R. 2003. *Modern Techniques of Raising Field Crops*. Oxford and IBH.
- Singh, S. S. 1998. *Crop Management*. Kalyani.

I.	Course title	:	**Agronomy of Medicinal, Aromatic and Underutilized Crops**
II.	Course code	:	**Agron. 508**
III.	Credit hours	:	**2 + 1**
IV.	Aim of the course	:	To acquaint the students with different medicinal, aromatic and underutilized field crops, their package of practices and processing

Theory

Unit I

Importance of medicinal and aromatic plants in human health, national economy and related industries, classification of medicinal and aromatic plants according to botanical characteristics and their uses, export potential and indigenous technical knowledge.

Unit II

Climate and soil requirements; cultural practices; yield and important constituents of medicinal plants (*Kacholam*, Sida, Indian long pepper, *Rauwolfia*, *Aloe vera*, *Satavar*, *Stevia*, *Chethikoduveli*, safed musli, kalmegh, asafoetida, *Nuxvomica*, etc).

Unit III

Climate and soil requirements; cultural practices; yield and important constituents of aromatic plants (citronella, palmarosa, mentha, basil, lemon grass, patchouli).

Unit IV

Climate and soil requirements; cultural practices; yield of under-utilized crops (rice bean, lathyrus, Sesbania, clusterbean, fenugreek, tobacco, betel vine, mango ginger, arrow root, grain amaranth, chia).

Unit V

Post harvest handling –drawing, processing, grading, packing and storage, value addition and quality standards in herbal products.

Practical

- Identification of crops based on morphological and seed characteristics
- Raising of herbarium of medicinal, aromatic and under-utilized plants
- Quality characters in medicinal and aromatic plants

- Methods of analysis of essential oil and other chemicals of importance in medicinaland aromatic plants.

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments and field visit

Learning outcome

Acquaintance with various medicinal and aromatic plants and their commercial base for developing entrepreneurship.

Suggested Reading

- Chadha, K. L. and Gupta, R. 1995. *Advances in Horticulture*. Vol. II. *Medicinal and Aromatic Plants*. Malhotra Pub
- Das, N. R. 2007. *Introduction to Crops of India*. Scientific Pub
- Handa, S. S. 1984. *Cultivation and Utilization of Medicinal Plants*. RRL, CSIR, Jammu.
- Hussain, A. 1984. *Essential Oil Plants and their Cultivation*. CIMAP, Lucknow.
- Hussain, A. 1993. *Medicinal Plants and their Cultivation*. CIMAP, Lucknow.
- ICAR [Indian Council of Agricultural Research]. 2006. *Hand Book of Agriculture.* ICAR, New Delhi.
- Kumar, N., Khader, M. A., Rangaswami, J. B. M., and Irulappan. 1997. *Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants*. Oxford and IBH.
- Prajapati, N. D., Purohit, S. S., Sharma. A. K., and Kumar, T. 2003. *A Hand Book of Medicinal Plants: A Complete Source Book.* Agrobios.
- Sharma, R. 2004. *Agro-Techniques of Medicinal Plants*. Daya Pub. House.

I.	Course title	:	**Agronomy of Fodder and Forage Crops**
II.	Course code	:	**Agron. 509**
III.	Credit hours	:	**2 + 1**
IV.	Aim of the course	:	To teach the crop husbandry of different forage and fodder crops along with their processing.

Theory

Unit I

Adaptation, distribution, varietal improvement, agro-techniques and quality aspects including anti-quality factors of important fodder crops like sorghum, maize, *bajra*, *guar*, cowpea, rice bean, subabul, desmanthes, stylo, oats, barley, berseem, *senji*, lucerne, etc.

Unit II

Adaptation, distribution, varietal improvement, agro-techniques and quality aspects including anti-quality factors of important forage crops/grasses, - Guinea grass, Napier grass, *Cenchrus*, congo signal, signal, gamba, setaria, para, deenanath, etc.

Unit III

Year-round fodder production and management, intercropping fodder crops in coconut garden, preservation and utilization of forage and pasture crops

Unit IV

Principles and methods of hay and silage making; chemical and biochemical changes, nutrient losses and factors affecting quality of hay and silage; use of physical and chemical enrichments and biological methods for improving nutrition; value additionof poor quality fodder. Fodder production through hydroponics. Azolla cultivation.

Unit V

Economics of forage cultivation uses and seed production techniques of important fodder crops.

Practical

- Practical training of farm operations in raising fodder crops;
- Canopy measurement, yield, Leaf: Stem ratio and quality estimation, *viz*., crude protein, NDF, ADF, lignin, silica, cellulose and IVDMD, etc. of various fodder andforage crops
- Anti-quality components like HCN in sorghum and such factors in other crops
- Hay and silage making and economics of their preparation.

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments and field visit

Learning outcome

Acquaintance with various fodder and forage crops and their commercial base for developing entrepreneurship.

Suggested Reading

- Chatterjee, B. N. 1989. *Forage Crop Production - Principles and Practices*. Oxford and IBH.
- Das, N. R. 2007. *Introduction to Crops of India*. Scientific Pub
- Narayanan, T. R. and Dabadghao, P. M. 1972. *Forage Crops of India*. ICAR.
- Singh, P. and Srivastava, A. K. 1990. *Forage Production Technology*. IGFRI, Jhansi.
- Singh, C., Singh, P., and Singh, R. 2003. *Modern Techniques of Raising Field Crops*. Oxford and IBH.
- Tejwani KG. 1994. *Agroforestry in India*. Oxford and IBH.

I.	Course title	**: Agrostology and Agro-forestry**
II.	Course code	**: Agron. 510**
III.	Credit hours	**: 2 + 1**
IV.	Aim of the course	: To teach the crop husbandry of different forage, fodder and agroforestry crops / trees along with their processing.

Theory

Unit I

Agrostology: definition and importance; principles of grassland ecology: grassland ecology – community, climax, dominant species, succession, biotype, ecological status of grasslands in India, grass cover of India; problems and management of grasslands.

Unit II

Importance, classification (various criteria), scope, status and research needs of pastures; pasture establishment, their improvement and renovation-natural pastures, cultivated pastures; common pasture grasses.

Unit III

Agroforestry: definition and importance; agroforestry systems, agrisilviculture, silvipasture, agrisilvipasture, agrihorticulture, aquasilviculture, alley cropping and energy plantation.

Unit IV

Crop production technology in agro-forestry and agrostology system; silvipastoral system: meaning and importance for wasteland devt.; selection of species, planting methods and problems of seed germination in agro-forestry systems; irrigation and manuring in agro-forestry ping and coppicing in agro- forestry systems; social acceptability and economic viability, nutritive value of trees; tender operation; desirable tree characteristics.

Practical

- Preparation of charts and maps of India showing different types of pastures andagro-forestry systems
- Identification of seeds and plants of common grasses, legumes and trees of economicimportance with reference to agro-forestry
- Seed treatment for better germination of farm vegetation
- Methods of propagation/ planting of grasses and trees in silvipastoral system
- Fertilizer application in strip and silvipastoral systems
- After-care of plantation
- Estimation of protein content in loppings of important fodder trees
- Estimation of calorie value of wood of important fuel trees
- Estimation of total biomass and fuel wood
- Economics of agro-forestry

- Visit to important agro-forestry research stations

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments and field visit.

Learning outcome

Basic knowledge on agroforestry, forage crops and their utility.

Suggested Reading

- Chatterjee, B. N. and Das, P. K. 1989. *Forage Crop Production. Principles and Practices.* Oxford and IBH.
- Dabadghao, P. M. and Shankaranarayan, K. A. 1973. *The Grass Cover in India*. ICAR.
- Dwivedi, A. P. 1992. *Agroforestry- Principles and Practices.* Oxford and IBH.
- ISA [Indian Society of Agronomy]. 1989. *Agroforestry System in India. Research and Development.* Indian Society of Agronomy, New Delhi.
- Narayan, T. R. and Dabadghao, P. M. 1972. *Forage Crop of India*. ICAR, New Delhi.

I.	Course title	**: Cropping System and Sustainable Agriculture**
II.	Course code	**: Agron. 511**
III.	Credit hours	**: 2 + 0**
IV.	Aim of the course	: To acquaint the students with the prevailing cropping systems and practices in the country and measures to improve their productivity.

Theory

Unit I

Cropping systems: definition, indices and its importance; physical resources, soil and water management in cropping systems; assessment of land use.

Unit II

Concept of sustainability in cropping systems and farming systems, scope and objectives; production potential under monoculture cropping, multiple cropping, alley cropping, sequential cropping and intercropping, mechanism of yield advantagein intercropping systems.

Unit III

Above and below ground interactions and allelopathic effects; competition relations; multi-storied cropping and yield stability in intercropping, role of non-monetary inputs and low cost technologies.

Unit IV

Sustainable agriculture – definition, pillars; Crop diversification for sustainability; role of organic matter in maintenance of soil fertility; crop residue management; fertilizer use efficiency and concept of fertilizer use in intensive cropping system. Research need on sustainable agriculture. Advanced nutritional tools for big data analysis and interpretation.

Unit V

Wetland – definition, conservation and cropping systems. Plant ideotypes for drylands and wetlands

Unit VI

Artificial Intelligence- concept and application in cropping systems.

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments.

Learning outcome

Basic knowledge on cropping system for sustainable agriculture.

Suggested Reading

- Panda, S. C. 2017. *Cropping Systems and Sustainable Agriculture*. Agrobios (India)
- Panda, S. C. 2018. *Cropping and Farming Systems*. Agrobios.
- Palaniappan, SP. and Sivaraman, K. 1996. *Cropping Systems in the Tropics; Principles and Management*. New Age.
- Panda, S. C. 2003. *Cropping and Farming Systems*. Agrobios.
- Reddy, S. R. 2000. *Principles of Crop Production*. Kalyani.
- Sankaran, S. and Mudaliar, T. V. S. 1997. *Principles of Agronomy*. The Bangalore Printing and Pub. Co.
- Singh, S. S. 2006. *Principles and Practices of Agronomy*. Kalyani.
- Tisdale, S. L., Nelson, W. L, Beaton, J. D., and Havlin, J. L. 1997. *Soil Fertility and Fertilizers*. Prentice Hall.

I.	Course title	**: Dryland Farming and Watershed Management**
II.	Course code	**: Agron. 512**
III.	Credit hours	**: 2 + 1**
IV.	Aim of the course	: To teach the basic concepts and practices of dryland farming and soil moisture conservation.

Theory

Unit I

Definition, concept and characteristics of dryland farming; dryland versus rainfed farming; significance and dimensions of dryland farming in Indian agriculture. Agencies and programmes in dryland agriculture in India.

Unit II

Soil and climatic parameters with special emphasis on rainfall characteristics; constraints limiting crop production in dryland areas; types of drought, characterization of environment for water availability; crop planning for erratic and aberrant weather conditions.

Unit III

Stress physiology and resistance to drought, adaptation of crop plants to drought, drought management strategies; preparation of appropriate crop plans for dryland areas; mid contingent plan for aberrant weather conditions.

Unit IV

Tillage, tilth, frequency and depth of cultivation, compaction in soil tillage; concept of conservation tillage; tillage in relation to weed control and moisture conservation; techniques and practices of soil moisture conservation (use of mulches, kinds, effectiveness and economics); antitranspirants; soil and crop management techniques, seeding and efficient fertilizer use. Measures to enhance water use efficiency in dryland crops.

Unit V

Concept of watershed, resource management, problems, approach and components.

Practical

- Method of seed priming
- Determination of moisture content on germination of important dryland crops
- Determination of relative water content and saturation deficit of leaf
- Moisture stress effects and recovery behaviour of important crops
- Estimation of Potential ET by Thornthwaite method
- Estimation of Reference ET by Penman Montieth Method
- Classification of climate by Thornthwaite method (based on moisture index, humidity index and aridity index)
- Classification of climate by Koppen Method
- Estimation of water balance by Thornthwaite method
- Estimation of water balance by FAO method
- Assessment of drought
- Estimation of length of growing period
- Estimation of probability of rain and crop planning for different drought condition
- Spray of anti-transpirants and their effect on crops
- Water use efficiency
- Visit to dryland research stations and watershed projects

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments.

Learning outcome

Basic knowledge on dryland farming and soil moisture conservation.

Suggested Reading

- Reddy, T. Y. 2018. *Dryland Agriculture Principles and Practices*, Kalyani Pub.
- Das, N. R. 2007. *Tillage and Crop Production*. Scientific Pub.
- Dhopte, A. M. 2002. *Agrotechnology for Dryland Farming*. Scientific Pub.
- Narayan V. V. D. 2002. *Soil and Water Conservation Research in India*. ICAR.
- Gupta, U. S. (Ed.). 1995. *Production and Improvements of Crops for Drylands*. Oxford and IBH.
- Katyal, J. C. and Farrington, J. 1995. *Research for Rainfed Farming*. CRIDA.
- Rao, S. C. and Ryan, J. 2007. *Challenges and Strategies of Dryland Agriculture*. Scientific Pub
- Singh, P. and Maliwal, P. L. 2005. *Technologies for Food Security and Sustainable Agriculture.* Agrotech Pub. Company.
- Singh, R. P. 1988. *Improved Agronomic Practices for Dryland Crops*. CRIDA.
- Singh, R. P. 2005. *Sustainable Development of Dryland Agriculture in India*. Scientific Pub.
- Singh, S. D. 1998. *Arid Land Irrigation and Ecological Management*. Scientific Pub
- Venkateshwarlu, J. 2004. *Rainfed Agriculture in India. Research and Development Scenario.* ICAR.

I.	Course title	**: Principles and Practices of Organic Farming**
II.	Course code	**: Agron. 513**
III.	Credit hours	**: 2 + 1**
IV.	Aim of the course	: To study the principles and practices of organic farming for sustainable crop production.

Theory

Unit I

Organic farming - concept and definition, its relevance to India and global agriculture and future prospects; principles of organic agriculture; organics and farming standards; organic farming and sustainable agriculture; selection and conversion of land, soil and water management - land use, conservation tillage; shelter zones, hedges, pasture management, agro-forestry.

Unit II

Organic farming and water use efficiency; soil fertility, nutrient recycling, organic residues, organic manures, composting, soil biota and decomposition of organic residues, earthworms and vermicompost, green manures, bio-fertilizers and biogas technology.

Unit III

Farming systems, selection of crops and crop rotations, multiple and relay cropping systems, intercropping in relation to maintenance of soil productivity.

Unit IV

Control of weeds, diseases and insect pest management, biological agents and pheromones, bio-pesticides.

Unit V

Socio-economic impacts; marketing and export potential: inspection, certification, labeling and accreditation procedures; organic farming and national economy.

Practical

- Method of making compost by aerobic method
- Method of making compost by anaerobic method
- Method of making vermicompost
- Identification and nursery raising of important agro-forestry tress and tress forshelter belts
- Efficient use of biofertilizers, technique of treating legume seeds with *Rhizobium* cultures, use of *Azotobacter*, *Azospirillum*, and PSB cultures in field
- Visit to a biogas plant
- Visit to an organic farm
- Quality standards, inspection, certification and labeling and accreditation procedures for farm produce from organic farms of entrepreneurship on organic inputs.

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments, exposure visit.

Learning outcome

Basic knowledge on organic farming for sustainable agriculture and development.

Suggested Reading

- Ananthakrishnan, T. N. (Ed.). 1992. *Emerging Trends in Biological Control of Phytophagous Insects*. Oxford and IBH.
- Gaur, A. C. 1982. *A Manual of Rural Composting*, FAO/UNDP Regional Project Document, FAO.
- Joshi, M. 2016. *New Vistas of Organic Farming*. Scientific Publishers
- Lampin, N. 1990. *Organic Farming*. Press Books, lpswitch, UK.

- Palaniappan, SP. and Anandurai, K. 1999. *Organic Farming – Theory and Practice.* Scientific Pub.
- Rao, B. V. V. 1995. *Small Farmer Focused Integrated Rural Development: Socio-economic Environment and Legal Perspective*: Pub3, Parisaraprajna Parishtana, Bangalore.
- Reddy, M. V. (Ed.). 1995. *Soil Organisms and Litter Decomposition in the Tropics*. Oxford and IBH.
- Sharma, A. 2002. *Hand Book of Organic Farming*. Agrobios.
- Singh, S. P. (Ed.). 1994. *Technology for Production of Natural Enemies.* PDBC, Bangalore.
- Rao, N. S. S. 2002. *Soil Microbiology*. Oxford and IBH.
- Trivedi, R. N. 1993. *A Text Book of Environmental Sciences*, Anmol Pub.
- Veeresh, G. K., Shivashankar, K., and Suiglachar, M. A. 1997. *Organic Farming and Sustainable Agriculture.* Association for Promotion of Organic Farming, Bangalore.
- WHO [World Health Organization]. 1990. *Public Health Impact of Pesticides Used in Agriculture*. WHO.
- Woolmer, P. L. and Swift, M. J. 1994. *The Biological Management of Tropical Soil Fertility*. TSBF and Wiley.

I.	Course title	**: Current Trends in Agronomy**
II.	Course code	**: Agron. 601**
III.	Credit hours	**: 3 + 0**
IV.	Aim of the course	: To acquaint the students with the recent advances in agricultural production.

Theory

Unit I

Agro-physiological basis of variation in yield, recent advances in soil plant-water relationship.

Unit II

Globalization of agriculture and WTO, precision agriculture, contract farming, organic farming, marketing and export potential of organic products, certification, labeling and accreditation procedures and ITK in farming.

Unit III

Crop residue management in multiple cropping systems; latest developments in plant management; Mechanization in crop production: modern agriculturalprecision tools and technologies, weed management, cropping systems, grassland management,agro-forestry, allelopathy.

Unit IV

GIS, GPS and remote sensing for crop management, global warming, GM crops, seed production technology; seed certification, seed multiplication, hybrid seed production etc.

Unit V

Concepts of system agriculture; holistic approach of farming systems, dryland farming, sustainable agriculture and research methodology in Agronomy. Conservation agriculture, principles, prospects and importance, potential benefits of CA under climate change scenario, policy issues.

Teaching methods / activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Recent advances in agricultural production.

Suggested Reading

- Agarwal, R. L. 1995. *Seed Technology*. Oxford and IBH.
- Dahiya, B. S. and Rai, K. N. 1997. *Seed Technology*. Kalyani.
- Govardhan, V. 2000. *Remote Sensing and Water Management in Command Areas: Agroecological Prospectives*. IBDC.
- ICAR [Indian Council of Agricultural Research]. 2006. *Hand Book of Agriculture*. ICAR.
- Narasaiah, M. L. 2004. *World Trade Organization and Agriculture*. Sonali Pub.
- Palaniappan, SP. and Annadurai, K. 2006. *Organic Farming - Theory and Practice*. Scientific Pub.
- Sen, S. and Ghosh, N. 1999. *Seed Science and Technology*. Kalyani.
- Tarafdar, J. C., Tripathi, K. P., and Kumar, M. 2007. *Organic Agriculture*. Scientific Pub.
- Kumar, R., Swarnkar, K. S., Singh, K. S., and Narayan, S. 2016. *A Text Book of Seed Technology*.Kalyani Pub.
- Reddy, S. R. and Prabhakara, G. 2015. *Dryland Agriculture*. Kalyani Pub.
- Gururajan, B., Balasubhramanian, R., and Swaminath, V. 2013. *Recent Strategies on Crop Production*. Kalyani Publishers.
- Venkateswarlu, B. and Arun K. S. 2009. *Climate change and agriculture: Adaptation and mitigation strategies*. *Indian J. Agron.* 54(2): 226-230.

I.	Course title	**: Recent Trends in Crop Growth and Productivity**
II.	Course code	**: Agron. 602**
III.	Credit hours	**: 2 + 1**

IV. Aim of the course : To study the physiology of vegetative and reproductive growth in relation to productivity of different crops under various environments.

Theory

Unit I

Plant density and crop productivity; plant and environmental factors, yield, plant distribution, strategies for maximizing solar energy utilization; leaf area; interception of solar radiation and crop growth; photosynthesis: the photosynthetic apparatus, factors essential for photosynthesis; difference in photosynthetic rates among and within species; physiological limitations to crop yield; solar radiation concept and agro-techniques for harvesting solar radiation.

Unit II

Growth analysis: concept, CGR, RGR, NAR, LAI, LAD, LAR; validity and Limitations in interpreting crop growth and development; growth curves: sigmoid, polynomial and asymptotic; root systems; root-shoot relationship; principles involved in inter and mixed cropping systems under rainfed and irrigated conditions; concept and differentiation of inter and mixed cropping; criteria in assessing the yield advantages.

Unit III

Competitive relationship and competition functions; biological and agronomic basis of yield advantage under intercropping; physiological principles of dryland crop production, constraints and remedial measures; heat unit concept of crop maturity: concept and types of heat units.

Unit IV

Concept of plant ideotypes: crop physiological and new ideotypes; characteristics of ideotype for wheat, rice, maize, etc.; concept and types of growth hormones; their role in field crop production; efficient use of resources.

Practical

- Field measurement of root-shoot relationship in crops at different growth stages
- Estimation of growth evaluating parameters like CGR, RGR, NAR, LAI etc., at different stages of crop growth
- Computation of harvest index of various crops
- Assessment of crop yield on the basis of yield attributing characters
- Construction of crop growth curves based on growth analysis data
- Computation of competition functions, viz. LER, IER aggressivity competition index, etc
- Senescence and abscission indices
- Analysis of productivity trend in un-irrigated areas
- Analysis of productivity trend in irrigated areas

Teaching methods / activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on the knowledge of crop growth for agricultural production.

Suggested Reading

- Chopra, V. L. and Paroda, R. S. 1984. *Approaches for Incorporation of Drought and Salinity Resistance in Crop Plants*. Oxford and IBH.
- Delvin, R. M. and Vitham, F. H. 1986. *Plant Physiology*. CBS Pub.
- Evans, L. T. 1975. *Crop Physiology*. Cambridge Univ. Press.
- Evans, L. T. 1996. *Crop Evolution, Adaptation and Yield*. Cambridge Univ. Press.
- Gupta, U. S. 1995. *Production and Improvement of Crops for Drylands*. Oxford and IBH.
- Gupta, U. S. 1988. *Progress in Crop Physiology*. Oxford and IBH.
- Kramer, P. J. and Boyer, J. S. 1995. *Water Relations of Plant and Soils.* Academic Press.
- Mukherjee, S. and Ghosh, A. K. 1996. *Plant Physiology*. Tata McGraw Hill.
- Narwal, S. S., Politycka, B., and Goswami, C. L. 2007. *Plant Physiology: Research Methods.*Scientific Pub.
- Tiaz, L. and Zeiger, E. 2006. *Plant Physiology*. Sinauer Associates, Inc.

I.	Course title	**: Irrigation Management**
II.	Course code	**: Agron. 603**
III.	Credit hours	**: 2 + 1**
IV.	Aim of the course	: To teach the students about optimization of irrigation in different crops under variable agro-climatic conditions.

Theory

Unit I

Global water resources; Water resources of India, irrigation projects during preand post independence period and their significance in crop production; irrigation needs, atmospheric, soil, agronomic, plant and water factors affecting irrigation need; water deficits and crop growth.

Unit II

Movement of water in soil-water movement under saturated and unsaturated conditions, Poiseuille's and Darcy's law, general equation of saturated and unsaturated flow of water in soil. Soil-plant-water relationships, evaporation, transpiration and evapo-transpiration, significance of transpiration, energy utilization in transpiration, physiological processes and crop productivity.

Unit III

Water requirement, irrigation needs, factors affecting irrigation need; water use efficiency, Infiltration; water movement under saturated and unsaturated conditions; management practices for improving water use efficiency of crops.

Unit IV

Soil and plant water potential, SPAC, transpiration and evapo-transpiration, significance of transpiration, energy utilization in transpiration, factors affecting ET, control of ET by mulching and use of anti-transpirants; fertilizer use in relationto irrigation.

Unit V

Crop water stress – water deficits and crop growth, adoptability of crops. Water availability in relation to nutrient availability.

Unit VI

Application of irrigation water, conveyance and distribution system, irrigation efficiency; agronomic considerations in the design and operation of irrigation projects; characteristics of irrigation and farming systems affecting irrigation management.

Unit VII

Strategies of using limited water supply; factors affecting ET, control of ET by mulching and use of anti-transpirants; fertilizer use in relation to irrigation; optimizing the use of given irrigation supplies.

Unit VIII

Land suitability for irrigation, land irrigability classification; integrated water management in command areas, institution of water management in commands, farmer's participation in command areas; irrigation legislation.

Unit IX

Economic analysis of irrigation and cop planning for optimum use of irrigation water

Unit X

Crop water production function

Practical

- Determination of water infiltration characteristics and water holding capacity ofsoil profiles.
- Determination Moisture extraction pattern of crops
- Determination of water balance component of transplanted rice by drum culturetechnique
- Determination of consumptive use and water requirement of a given croppingpattern
- Determination of crop efficient of one important crop
- Planning, designing and installation of drip irrigation system
- Planning, designing and installation of sprinkler irrigation system
- Designing of drainage channel

- Measurement of irrigation efficiencies
- Determination of irrigation timing under different methods of irrigation
- Visit to irrigation command area

Teaching methods / activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Management of irrigation water for sustainable agriculture.

Suggested Reading

- Singh, M. P. 2017. *Recent Advances in Irrigation Water Management*. Kalyani Pub.
- FAO [Food and Agriculture Organization of the United Nations]. 1984. *Irrigation Practice and Water Management.* Oxford and IBH.
- Michael, A. M. 1978. *Irrigation: Theory and Practice*. Vikas Pub.
- Mishra, R. R. and Ahmad, M. 1987. *Manual on Irrigation and Agronomy*. Oxford and IBH.
- Panda, S. C. 2003. *Principles and Practices of Water Management.* Agrobios.
- Reddy, S. R. 2000. *Principles of Crop Production*. Kalyani.
- Reddy, G. H. S. and Reddy, T. Y. 1995. Efficient Use of Irrigation Water. In: Gupta US. (Ed.). *Production and Improvement of Crops for Drylands*. Oxford and IBH.
- Singh, S. S. 2006. Principles and practices of Agronomy. In: Gupta, U. S. (Ed.). *Production and Improvement of Crops for Drylands*. Oxford and IBH

I.	Course title	**: Recent Trends in Weed Management**
II.	Course code	**: Agron. 604**
III.	Credit hours	**: 2 + 0**
IV.	Aim of the course	: To teach the students about the changing weed flora, new herbicides, their resistance, toxicity, antidotes and residue management under different cropping systems.

Theory

Unit I

Crop-weed competition in different cropping situations; changes in weed flora, various causes and effects; different methods of weed management. Migration, introduction, adaptation of weeds, Invasive weeds – biology and management. Different mechanisms of invasion – present status and factors influencing weed invasion.

Unit II

Physiological and biological aspects of herbicides, their absorption, translocation, metabolism and mode of action; selectivity of herbicides and factors affecting them.

Unit III

Climatic factors and phytotoxicity of herbicides; fate of herbicides in soil and factors affecting them, Degradation of herbicides in soil and plants- factors affecting it, primary and secondary metabolites, residue management of herbicides, adjuvants.

Unit IV

Advances in herbicide products and application techniques and methods; use of drones; herbicide resistance; antidotes and crop protection compatibility of herbicides of different groups; compatibility of herbicides with other pesticides; herbicide rotation and herbicide mixtures.

Unit V

Development of transgenic herbicide resistant crops; herbicide development, registration procedures.

Unit VI

Relationship of herbicides with tillage, fertilizer, and irrigation, cropping system; bioherbicides, allelochemical and alleloherbicides, herbicide bioassays. Recent advances in nonchemical weed management including deleterious rhizobacteria, robotics, biodegradable film, etc.

Teaching methods / activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on the knowledge of new herbicides, their resistance, toxicity, antidotes and residue management under different cropping systems.

Suggested Reading

- Böger, P., Wakabayashi, K., and Hirai, K. (Eds.). 2002. *Herbicide Classes in Development*. *Mode of Action*, *Targets*, *Genetic Engineering*, *Chemistry*. Springer.
- Das, T. K. 2008. *Weed Science: Basics and Applications*, Jain Brothers (New Delhi)
- Fennimore, S. A. and Bell, C. 2014. *Principles of Weed Control*. 4th Ed, California Weed Sci. Soc.
- Gupta, O. P. 2007. *Weed Management: Principles and Practices*, 2nd Ed.
- Jugulan, M. (Ed.). 2017. *Biology, Physiology and Molecular Biology of Weeds*. CRC Press
- Monaco, T. J., Weller, S. C., and Ashton, F. M. 2014. *Weed Science Principles and Practices*. Wiley
- Powles, S. B. and Shaner, D. L. 2001. *Herbicide Resistance and World Grains*, CRC Press.
- Walia, U. S. 2006. *Weed Management.* Kalyani.
- Zimdahl, R. L. (Ed.). 2018. *Integrated Weed Management for Sustainable Agriculture.* B. D. Sci. Pub.

I.	Course title	**: Integrated Farming Systems for Sustainable Agriculture**
II.	Course code	**: Agron. 605**
III.	Credit hours	**: 2 + 0**
IV.	Aim of the course	: To appraise about different enterprises suitable for different agro-climatic conditions for sustainable agriculture.

Theory

Unit I

Integrated Farming systems (IFS): definition, scope and importance; classification of IFS based on enterprises as well as under rainfed/irrigated condition in different land situation. farming systems according to type of rotation, intensity of rotation,degree of commercialization, water supply, enterprises.

Unit II

Concept of sustainability in of Integrated farming systems; efficient Integrated farming systems based on economic viability and natural resources - identification and management.

Unit III

Production potential of different components of Integrated farming systems; interaction and mechanism of different production factors; stability of Integrated Farming system based on research/long term information. in different systems through research; eco-physiological approaches to intercropping. Integration ofcomponents and adaptability of different farming system based on land situations and climatic condition of a region; evaluation of IFS.

Unit IV

Simulation models for intercropping; soil nutrient in intercropping; preparation of different farming system models; evaluation of different farming systems. Formulation of different Integrated Farming system models; evaluation of different Integrated Farming system models. Recycling of organic waste in farming systemsand in IFS.

Unit V

New concepts and approaches of farming system and organic farming; value addition, waste recycling, quantification and mitigation of Green House gases; case studies/ success stories of different Integrated Farming systems. cropping systems and organic farming; case studies on different farming systems. Possible use of ITK in Integrated farming system.

Teaching methods / activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on the knowledge of enterprises suitable for different agroclimatic conditions for sustainable agriculture and their proper untilization.

Suggested Reading

- Ananthakrishnan, T. N. (Ed.). 1992. *Emerging Trends in Biological Control of Phytophagous Insects*. Oxford and IBH.
- Baishya, A., Borah, M., Das, A. K., Hazarika, J., Gogoi, B., and Borah, A. S. 2017. *Waste Recycling through Integrated Farming Systems. An Assam Agriculture Experience*. Éditions Universitaires Européennes, Germany.
- Balasubramanian, P. and Palaniappan, SP. 2006. *Principles and Practices of Agronomy*. Agrobios.
- Edens, T. 1984. *Sustainable Agriculture and Integrated Farming System*. Michigan State Univ. press.
- Jayanthi, C. 2006. *Integrated Farming Systems-A Way to Sustainable Agriculture*. Tamil Nadu Agricultural University, Coimbatore
- Joshi, M. and Parbhakarasetty, T. K. 2005. *Sustainability through Organic Farming*. Kalyani Publishers
- Kolhapure, A., Madhukar, D., and Shete, B. 2014. *A Text Book of Farming System and Sustainable Agriculture.* Universal Prakashan, Pune.
- Palaniappan, SP. and Anandurai, K. 1999. *Organic Farming - Theory and Practice*. Scientific Pub
- Panda, S. C. 2004. *Cropping Systems and Farming Systems*. Agrobios.
- Lampin, N. 1990. *Organic Farming*. Farming Press Books.
- Ravisankar, D. and Jayanthi, C. 2015. *Farming Systems: Concepts and Approaches*. Agrobios.

I.	Course title	**: Soil Conservation and Watershed Management**
II.	Course code	**: Agron. 606**
III.	Credit hours	**: 2 + 1**
IV.	Aim of the course	: To teach about different soil moisture conservation technologies for enhancing the agricultural productivity through a holistic approach based on watershed management.

Theory

Unit I

Soil erosion: definition, nature and extent of erosion; types of erosion, factors affecting erosion

Unit II

Soil conservation: definition, methods of soil conservation; agronomic measures - contour cultivation, strip cropping, cover crops; mulching, tillage, cropping system vegetative barriers; improved dry farming practices; mechanical measures - bunding, gully control, bench terracing; role of grasses and pastures in soil conservation; wind breaks and shelter belts.

Unit III

Watershed management: definition, objectives, concepts, approach, components,steps in implementation of watershed; development of cropping systems for watershed areas. Remote sensing in watershed management.

Unit IV

Land use capability classification, alternate land use systems; agro-forestry; ley farming; *jhum* management - basic concepts, socio-ethnic aspects, its layout.

Unit V

Drainage, methods of drainage, Drainage considerations and agronomic management; rehabilitation of abandoned *jhum* lands and measures to prevent soil erosion.

Practical

- Study of different types of erosion
- Determination of dispersion ratio
- Estimation of soil loss by Universal Soil Loss Equation
- Estimation of soil loss by wind erosion
- Measurement of runoff and soil loss
- Field studies of different soil conservation measures
- Laying out run-off plot and deciding treatments
- Identification of different grasses and trees for soil conservation
- Visit to watershed areas
- Visit to a soil conservation research centre, demonstration and training centre

Teaching methods / activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on the knowledge of soil moisture conservation technologies for enhancing the agricultural productivity through holistic approach on watershed management.

Suggested Reading

- Arakeri, H. R. and Roy, D. 1984. *Principles of Soil Conservation and Water Management*. Oxfordand IBH.
- Dhruvanarayana, V. V. 1993. *Soil and Water Conservation Research in India*. ICAR.

- FAO [Food and Agriculture Organization of the United Nations]. 2004. *Soil and Water Conservation in Semi-Arid Areas. Soils Bull.,* Paper 57. FAO, Rome.
- Frederick, R. T., Hobbs, J., Arthur, D., and Roy, L. 1999. *Soil and Water Conservation: Productivity and Environment Protection.* 3rd Ed. Prentice Hall.
- Singh, G., Venkataraman, C. G., Sastry, B., and Joshi, P. 1990. *Manual of Soil and Water Conservation Practices*. Oxford and IBH.
- Murthy, V. V. N. 1995. *Land and Water Management Engineering*. Kalyani.
- Tripathi, R. P. and Singh, H. P. 1993. *Soil Erosion and Conservation*. Wiley Eastern.
- Reddy, T. Y. and Reddy, G. H. S. 1992. *Principles of Agronomy*. Kalyani.

I.	Course title	**: Stress Crop Production**
II.	Course code	**: Agron. 607**
III.	Credit hours	**: 2 + 1**
IV.	Aim of the course	: To study the various types of stresses in crop production and strategies to overcome them.

Theory

Unit I

Stress and strain terminology; nature and stress injury and resistance; causes of stress.

Unit II

Low temperature stress: freezing injury and resistance in plants, measurement of freezing tolerance, chilling injury and resistance in plants, practical ways to overcome the effect of low temperature stress through, soil and crop manipulations.

Unit III

High temperature or heat stress: meaning of heat stress, heat injury and resistance in plants, practical ways to overcome the effect of heat stress through soil and crop manipulations.

Unit IV

Water deficit stress: meaning of plant water deficient stress and its effect on growth and development, water deficit injury and resistance, practical ways to overcome effect of water deficit stress through soil and crop, manipulations.

Unit V

Excess water or flooding stress: meaning of excess water stress, its kindsand effects on crop plants, excess water stress injury and resistance, practical ways to overcome excess water stress through soil and crop manipulations.

Unit VI

Salt stress: meaning of salt stress and its effect on crop growth, salt stress injury and resistance in plants, practical ways to overcome the effect of salt stress throughsoil and crop manipulations.

Unit VII

Mechanical impedance of soil and its impact on plant growth; measures to overcome soil mechanical impedance.

Unit VIII

Environmental pollution: air, soil and water pollution, and their effect on crop growth and quality of produce; ways and means to prevent environmental pollution.

Practical

- Determination of electrical conductivity of plant cell sap
- Determination of osmotic potential and tissue water potential
- Measurement of transpiration rate
- Measurement of stomatal frequency
- Measurement of Relative Water Content of leaf
- Measurement of electrolytic leakage
- Growing of plants in sand culture under salt stress for biochemical and physiologicalstudies
- Studies on effect of osmotic and ionic stress on seed germination and seedlinggrowth
- Measurement of low temperature injury under field conditions
- Studies on plant responses to excess water.

Teaching methods / activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome

Experience on the knowledge of various types of stresses in crop production and strategies to overcome these .

Suggested Reading

- Baker, F. W. G. 1989. *Drought Resistance in Cereals*. Oxon, UK.
- Gupta, U. S. (Ed.). 1988. *Physiological Aspects of Dryland Farming*. Oxford and IBH.
- Kramer, P. J. 1983. *Water Relations of Plants*. Academic Press.
- Levitt, J. 1980. *Response of Plants to Environmental Stresses*. Vols. I, II. Academic Press.
- Mavi, H. S. 1978. *Introduction to Agro-meteorology*. Oxford and IBH.
- Michael, A. M. and Ojha, T. P. 1981. *Principles of Agricultural Engineering*. Vol II. Jain Bros.

- Nilsen, E. T. and Orcut, D. M. 1996. *Physiology of Plants under Stress – Abiotic Factors*. John Wiley and Sons.
- Singh, K. 2000. *Plant Productivity under Environmental Stress*. Agrobios.
- Singh, K. N. and Singh, R. P. 1990. *Agronomic Research towards Sustainable Agriculture*. Indian Society of Agronomy, New Delhi.
- Somani, L. L. and Totawat, K. L. 1992. *Management of Salt-affected Soils and Waters.* Agrotech P
- Virmani, S. M., Katyal, J. C., Eswaran, H., and Abrol, I. P. 1994. *Stressed Ecosystem and Sustainable Agriculture*. Oxford and IBH

I.	Course title	**: Research and Publication Ethics**
II.	Course code	**: Agron. 608**
III.	Credit hours	**: 2 + 0**
IV.	Aim of the course	: To sensitize the students on the different aspects of research, and ethics related to publication.

Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit IV

Publication ethics: Definition, introduction and importance. Best practices/standard setting initiatives and guidelines: COPE, WAME, etc., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatory publishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to check publisher copy right and self archiving policies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools *viz*., JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open source software tools

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, etc. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index altmetrics.

Teaching methods / activities

Classroom teaching with AV aids, group discussion, assignments.

Learning outcome

Development of skill for research management and quality publication.

Suggested Reading

- Beall, J. 2012. Predatory publishers are corrupting open access. *Nature* 489(7415): 179-179. Available : https://doi.org/10.1038/489179a
- Bird, A. 2006. *Philosophy of Science*. Routledge, London, 328p.
- Chaddah, P. 2018. *Ethics in Competitive Research: Do Not Get Scooped; Do Not Get Plagiarized.* ISBN: 978-9387480865, 128p.
- INSA [Indian National Science Academy]. 2019. *Ethics in Science Education, Research and Governance*.ISBN:978-81-939482-1-7. Available: https: // www. insaindia. res. in/ pdf / Ethics_Book.pdf.
- Mac Intyre, A. 1967. *A Short History of Ethics*. Macmillan Pub. Co., New York, 280p.
- NASEM [National Academy of Sciences, National Academy of Engineeringand Institute of Medicine]. 2009. *On Being a Scientist: A Guide to Responsible Conduct in Research*. (3rd Ed). National Academies Press, USA, 65p.
- Resnik, D.B. 2015. What is ethics in research and why is it important. National institute of Environmental Health Science, pp. 1-10 Available : https: / /www .niehs.nih.gov / research / resources / bioethics / whatis / index.cfm
- Thomas, C. G. 2018. *Research Methodology and Scientific Writing*. (2nd Ed.). Ane Books Pvt. Ltd., New Delhi, 627p.

SOIL SCIENCE

Course Title with Credit Load for M.Sc. in Soil Science

Course Code	Course Title	Credit Hours
*Soil 501	Soil physics	2+1
*Soil 502	Soil fertility and fertilizer use	3+1
*Soil 503	Soil chemistry	2+1
*Soil 504	Soil mineralogy, genesis and classification	2+1
Soil 505	Soil erosion and conservation	2+1
*Soil 506	Soil Biology and Biochemistry	2+1
Soil 507	Radioisotopes in soil and plant studies	1+1
Soil 508	Soil, water and air pollution	2+1
Soil 509	Remote Sensing and GIS Technique for Soil, Water andCrop Studies	2+1
*Soil 510	Analytical technique and instrumental methods in soil and plant analysis	0+2
Soil 511	Management of problem soils and water	2+1
Soil 512	Land degradation and restoration	1+0
Soil 513	Soil Survey and Land use Planning	2+0
Soil 514	Introduction to nanotechnology	2+1
Soil 591	Master's Seminar	0+1
Soil 599	Master's Research	0+30

*Indicates Core Courses which are Compulsory for Master Programme

I. **Course Title** : **Soil Physics**
II. **Course Code** : **Soil 501**
III. **Credit Hours** : **2+1**
IV. **Aim of the course**

To impart basic knowledge about soil physical properties and processes in relation to plant growth.

V. **Theory**

Unit I

Basic principles of physics applied to soils, soil as a three phase system.

Unit II

Soil texture, textural classes, mechanical analysis, specific surface.

Unit III

Soil consistence; dispersion and workability of soils; soil compaction and consolidation; soil strength; swelling and shrinkage - basic concepts. Alleviation of soil physical constraints for crop production. Soil erosion and edibility

Unit IV

Soil structure - genesis, types, characterization and management, soil structure; soil aggregation, aggregate stability; soil tilth, characteristics of good soil tilth; soil crusting -mechanism, factors affecting and evaluation; soil conditioners; puddling, its effect on soil physical properties; clod formation.

Unit V

Soil water: content and potential, soil water retention, soil-water constants, measurement of soil water content, energy state of soil water, soil water potential, soil-moisture characteristic curve; hysteresis, measurement of soil-moisture potential.

Unit VI

Water flow in saturated and unsaturated soils, Poiseuille's law, Darcy's law; hydraulic conductivity, permeability and fluidity, hydraulic diffusivity; measurement of hydraulic conductivity in saturated and unsaturated soils.

Unit VII

Infiltration; internal drainage and redistribution; evaporation; hydrologic cycle, field water balance; soil-plant-atmosphere continuum.

Unit VIII

Composition of soil air; renewal of soil air - convective flow and diffusion; measurement of soil aeration; aeration requirement for plant growth; soil air management.

Unit IX

Modes of energy transfer in soils; energy balance; thermal properties of soil; measurement of soil temperature; soil temperature in relation to plant growth; soil temperature management. Soil colour- classification, importance and identification.

VI. Practical

- Determination of B.D, P.D and mass volume relationship of soil, Mechanical analysis by hydrometer and international pipette method
- Measurement of Atterberg limits, Aggregate analysis - dry and wet, Measurement of soil-water content by different methods, Measurement of soil-water potential by using tensiometer and gypsum Blocks, Determination of soil-moisture characteristics curve and computation of pore-size, distribution, Determination of hydraulic conductivity under saturated and unsaturated conditions, Determination of infiltration rate of soil, Determination of aeration porosity and oxygen diffusion rate, Soil temperature measurements by different methods, Estimation of water balance components in bare and cropped fields.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Baver LD, Gardner WH and Gardner WR. 1972. *Soil Physics*. John Wiley & Sons.
- Ghildyal BP and Tripathi RP. 2001. *Soil Physics*. New Age International.
- Hanks JR and Ashcroft GL. 1980. *Applied Soil Physics*. Springer Verlag.
- Hillel D. 1972. *Optimizing the Soil Physical Environment toward Greater Crop Yields*. Academic Press.
- Hillel D. 1980. *Applications of Soil Physics*. Academic Press.
- Hillel D. 1980. *Fundamentals of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physic*s. Academic Press.
- Hillel D. 2003. *Introduction to Environmental Soil Physics*. Academic Press.
- Indian Society of Soil Science. 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Kirkham D and Powers WL. 1972. *Advanced Soil Physics*. Wiley-Interscience.
- Kohnke H. 1968. *Soil Physics*. McGraw Hill.

- Lal R and Shukla MK. 2004. *Principles of Soil Physics*. Marcel Dekker.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. **Course Title** : **Soil Fertility and Fertilizer Use**

II. **Course Code** : **Soil 502**

III. **Credit Hours** : **3+1**

IV. **Aim of the course**

To impart knowledge about soil fertility and its control, and to understand the role of fertilizers and manures in supplying nutrients to plants so as to achieve high fertilizer use efficiency.

V. **Theory**

Unit I

Soil fertility and soil productivity; fertility status of major soils group of India; nutrient sources – fertilizers and manures; Criteria of essentiality, classification, law of minimum and maximum, essential plant nutrients - functions and deficiency symptoms, Nutrient uptake, nutrient interactions in soils and plants; long term effect of manures and fertilizers on soil fertility and crop productivity.

Unit II

Soil and fertilizer nitrogen – sources, forms, immobilization and mineralization, nitrification, denitrification; biological nitrogen fixation -types, mechanism, microorganisms and factors affecting; nitrogenous fertilizers and their fate in soils; management of fertilizer nitrogen in lowland and upland conditions for high fertilizer use efficiency.

Unit III

Soil and fertilizer phosphorus - forms, immobilization, mineralization, reactions in acid and alkali soils; factors affecting phosphorus availability in soils; phosphatic fertilizers - behavior in soils and management under field conditions. Potassium - forms, equilibrium in soils and its agricultural significance; mechanism of potassium fixation; management of potassium fertilizers under field conditions.

Unit V

Sulphur - source, forms, fertilizers and their behavior in soils; role in crops and human health; calcium and magnesium– factors affecting their availability in soils; management of sulphur, calcium and magnesium fertilizers.

Unit VI

Micronutrients – critical limits in soils and plants; factors affecting their availability and correction of their deficiencies in plants; role of chelates in nutrient availability.

Unit VII

Common soil test methods for fertilizer recommendations; quantity– intensity relationships; soil test crop response correlations and response functions.

Unit VIII

Fertilizer use efficiency; site-specific nutrient management; plant need based nutrient management; integrated nutrient management; specialty fertilizers concept, need and category. Current status of specialty fertilizers use in soils and crops of India;

Unit IX

Soil fertility evaluation - biological methods, soil, plant and tissue tests; soil quality in relation to sustainable agriculture, Determination of critical limit,DRIS

Unit X

Definition and concepts of soil health and soil quality; Long term effects of fertilizers and soil quality.

VI. Practical

- Soil and plant sampling and processing for chemical analysis
- Determination of soil pH, total and organic carbon in soil
- Chemical analysis of soil for total and available nutrients (major and micro)
- Analysis of plants for essential elements (major and micro)

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil fertility and fertilizers in relation to plant growth and development.

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- Kabata-Pendias A and Pendias H. 1992. *Trace Elements in Soils and Plants*. CRC Press.
- Kannaiyan S, Kumar K and Govindarajan K. 2004. *Biofertilizers Technology*. Scientific Publ.
- Leigh J G. 2002. *Nitrogen Fixation at the Millennium*. Elsevier.
- Mengel K and Kirkby EA. 1982. *Principles of Plant Nutrition*. International

Potash Institute, Switzerland.

- Mortvedt JJ, Shuman LM, Cox FR and Welch RM. 1991. *Micronutrients in Agriculture*. 2nd Ed. SSSA, Madison.
- Pierzinsky GM, Sims TJ and Vance JF. 2002. *Soils and Environmental Quality*. 2nd Ed. CRC Press.
- Stevenson FJ and Cole MA. 1999. *Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulphur, Micronutrients*. John Wiley & Sons.
- Tisdale SL, Nelson SL, Beaton JD and Havlin JL. 1999. *Soil Fertility and Fertilizers.* 5th Ed. Prentice Hall of India.
- Troeh FR and Thompson LM. 2005. *Soils and Soil Fertility*. Blackwell.

I. Course Title : Soil Chemistry

II. Course Code : Soil 503

III. Credit Hours : 2+1

IV. Aim of the course

To introduce the classical concepts of soil chemistry and to familiarize students with modern developments in chemistry of soils in relation to using soils as a medium for plant growth.

V. Theory

Unit I

Chemical (elemental) composition of the earth's crust, soils, rocks and minerals

Unit II

Elements of equilibrium thermodynamics, chemical equilibria, electrochemistry and chemical kinetics.

Unit III

Soil colloids: inorganic and organic colloids - origin of charge, concept of point of zero-charge (PZC) and its dependence on variable-charge soil components, surface charge characteristics of soils; diffuse double layer theories of soil colloids, zeta potential, stability, coagulation/flocculation and peptization of soil colloids; electrometric properties of soil colloids; sorption properties of soil colloids; soil organic matter - fractionation of soil organic matter and different fractions, Characterization of OM; clay-organic interactions.

Unit IV

Ion exchange processes in soil; cation exchange- theories based on law of mass action (Kerr-Vanselow, Gapon equations, hysteresis, Jenny's concept), adsorption isotherms, Donnan-membrane equilibrium concept, clay-membrane electrodes and ionic activity measurement, thermodynamics, statistical mechanics; anion and ligand exchange– Inner sphere and outer-sphere surface complex formation, fixation of oxyanions, Hysteresis in sorption-desorption of oxy-anions and anions, shift of PZC on ligand exchange, AEC, CEC; experimental methods to study ion exchange phenomena and practical implications in plant nutrition.

Unit V

Potassium, phosphate and ammonium fixation in soils covering specific and non-specific sorption; precipitation-dissolution equilibria; Concept of quantity/intensity (Q/ I) relationship; step and constant-rate K; management aspects.

Unit VI

Chemistry of acid soils; active and potential acidity; lime potential, chemistry of acid soils; sub-soil acidity.

Unit VII

Chemistry of salt-affected soils and amendments; soil pH, ECe, ESP, SAR and important relations; soil management and amendments.

Unit VIII

Chemistry and electrochemistry of submerged soils, geochemistry of micronutrients, environmental soil chemistry

VI. Practical

Preparation of saturation extract, measurement of pH, EC, CO, HCO, Ca, Mg, K and Na, Determination of CEC and AEC of soils, Analysis of equilibrium soil solution for pH, EC, Eh by the use of Eh-pH meter and conductivity meter, Determination of point of zero-charge and associated surface charge characteristics by the serial potentiometric titration method, Extraction of humic substances, Potentiometric and conductometric titration of soil humic and fulvic acids, (E4/E6) ratio of soil humic and fulvic acids by visible spectrophotometric studies and the D (E4/E6) values at two pH values, Adsorption-desorption of phosphate/sulphate by soil using simple adsorption isotherm, Construction of adsorption envelope of soils by using phosphate/fluoride/sulphate and ascertaining the mechanism of the ligand exchange process involved, Determination of titratable acidity of an acid soil by $BaCl_2$-TEA method, Determination of Q/I relationship of potassium, Determination of lime requirement of an acid soil by buffer method, Determination of gypsum requirement of an alkali soil.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of chemical behaviour of soil and their utility in research for solving field problem.

IX. Suggested Reading

- Bear RE. 1964. *Chemistry of the Soil.* Oxford and IBH.
- Bolt GH and Bruggenwert MGM. 1978. *Soil Chemistry*. Elsevier.
- Greenland DJ and Hayes MHB. 1981. *Chemistry of Soil Processes*. John Wiley & Sons.
- Greenland DJ and Hayes MHB. *Chemistry of Soil Constituents*. John Wiley & Sons.
- McBride MB. 1994. *Environmental Chemistry of Soils.* Oxford University Press.
- Sposito G. 1981. *The Thermodynamics of Soil Solutions*. Oxford University Press.
- Sposito G. 1984. *The Surface Chemistry of Soils*. Oxford University Press.
- Sposito G. 1989. *The Chemistry of Soils*. Oxford University Press.
- Stevenson FJ. 1994. *Humus Chemistry*. 2nd Ed. John Wiley & Sons.
- Van Olphan H. 1977. *Introduction to Clay Colloid Chemistry*. John Wiley & Sons.

I. Course Title : Soil Mineralogy, Genesis and Classification
II. Course Code : Soil 504
III. Credit Hours : 2+1
IV. Aim of the course

To acquaint students with basic structure of alumino-silicate minerals and genesis of clay minerals; soil genesis in terms of factors and processes of soil formation, and to enable students conduct soil survey and interpret soil survey reports in terms of land use planning.

V. Theory

Unit I

Fundamentals of crystallography, space lattice, coordination theory, isomorphism and polymorphism.

Unit II

Classification, structure, chemical composition and properties of clay minerals;

genesis and transformation of crystal line and non-crystal line clay minerals; identification techniques; amorphous soil constituents and other non-crystalline silicate minerals and their identification; clay minerals in Indian soils, role of clay minerals in plant nutrition, interaction of clay with humus, pesticides and heavy metals.

Unit III

Factors of soil formation, soil formation models; soil forming processes; weathering of rocks and mineral transformations; soil profile; weathering sequences of minerals with special reference to Indian soils.

Unit IV

Concept of soil individual; soil classification systems – historical developments and modern systems of soil classification with special emphasis on soil taxonomy; soil classification, soil mineralogy and soil maps – usefulness.

VI. Practical

- Separation of sand, silt and clay fraction from soil
- Determination of specific surface area and CEC of clay
- Identification and quantification of minerals in soil fractions
- Morphological properties of soil profile in different land forms
- Classification of soils using soil taxonomy
- Calculation of weathering indices and its application in soil formation
- Grouping soils using available database in terms of soil quality

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil taxonomy and genesis and their utility in research for solving field problem.

Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu. Buol EW, Hole ED, MacCracken RJ and Southard RJ. 1997. *Soil Genesis and Classification*. 4th Ed. Panima Publ.
- Dixon JB and Weed SB. 1989. *Minerals in Soil Environments*. 2nd Ed. Soil Science Society of America, Madison.

- Grim RE. 1968. *Clay Mineralogy*. McGraw Hill.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Sehgal J. 2002. *Introductory Pedology: Concepts and Applications*. New Delhi
- Sehgal J. 2002. *Pedology - Concepts and Applications*. Kalyani.
- USDA. 1999. *Soil Taxonomy*. Hand Book No**.** 436. 2nd Ed. USDA NRCS, Washington.
- Wade FA and Mattox RB. 1960. *Elements of Crystallography and Mineralogy*. Oxford & IBH.
- Wilding LP and Smeck NE. 1983. *Pedogenesis and Soil Taxonomy*: II. *The Soil Orders*.

Elsevier.

- Wilding NE and Holl GF. (Eds.). 1983. *Pedogenesis and Soil Taxonomy*. I.

I. **Course Title : Soil Erosion and Conservation**

II. **Course Code : Soil 505**

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

IV. **Aim of the course**

To enable students to understand various types of soil erosion and measures to be taken for controlling soil erosion to conserve soil and water.

V. **Theory**

Unit I

History, distribution, identification and description of soil erosion problems in India.

Unit II

Forms of soil erosion; effects of soil erosion and factors affecting soil erosion; types and mechanisms of water erosion; raindrops and soil erosion; rainfall erosivity - estimation as EI30 index and kinetic energy; factors affecting water erosion; empirical and quantitative estimation of water erosion; methods of measurement and prediction of runoff; soil losses in relation to soil properties and precipitation.

Unit III

Wind erosion- types, mechanism and factors affecting wind erosion; extent of problem in the country.

Unit IV

Principles of erosion control; erosion control measures – agronomical and engineering; erosion control structures - their design and layout.

Unit V

Soil conservation planning; land capability classification; soil conservation in special problem areas such as hilly, arid and semi-arid regions, waterlogged and wet lands.

Unit VI

Watershed management - concept, objectives and approach; water harvesting and recycling; flood control in watershed management; socioeconomic aspects of watershed management; case studies in respect to monitoring and evaluation of watersheds; use of remote sensing in assessment and planning of watersheds, sediment measurement

VI. Practical

- Determination of different soil erodibility indices - suspension percentage, dispersion ratio, erosion ratio, clay ratio, clay/moisture equivalent ratio, percolation ratio, raindrop erodibility index
- Computation of kinetic energy of falling rain drops
- Computation of rainfall erosivity index (EI30) using rain gauge data
- Land capability classification of a watershed
- Visits to a watersheds

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil conservation and their utility in research for solving field problem.

IX. Suggested Reading

- Biswas TD and Narayanasamy G. (Eds.) 1996. *Soil Management in Relation to Land Degradation and Environment*. Bull. Indian Society of Soil Science No. 17.
- Doran JW and Jones AJ. 1996. *Methods of Assessing Soil Quality*. Soil Science Society of America, Spl Publ. No. 49, Madison, USA.
- Gurmal Singh, Venkataramanan C, Sastry G and Joshi BP. 1990. *Manual of*

Soil and Water Conservation Practices*. Oxford & IBH.

- Hudson N. 1995. *Soil Conservation*. Iowa State University Press.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. Course Title : Soil Biology and Biochemistry
II. Course Code : Soil 506
III. Credit Hours : 2+1

IV. Aim of the course

To teach students the basics of soil biology and biochemistry, including biogeochemical cycles, plant growth promoting rhizobacteria, microbial interactions in soil and other soil activities.

V. Theory

Unit I

Soil biota, soil microbial ecology, types of organisms in different soils; soil microbial biomass; microbial interactions; un-culturable soil biota.

Unit II

Microbiology and biochemistry of root-soil interface; phyllosphere; soil enzymes, origin, activities and importance; soil characteristics influencing growth and activity of microflora; Root rhizosphere and PGPR.

Unit III

Microbial transformations of nitrogen, phosphorus, sulphur, iron and manganese in soil; biochemical composition and biodegradation of soil organic matter and crop residues, microbiology and biochemistry of decomposition of carbonaceous and proteinaceous materials, cycles of important organic nutrients.

Unit IV

organic wastes and their use for production of biogas and manures; bioticfactors in soil development; microbial toxins in the soil.

Unit V

Preparation and preservation of farmyard manure, animal manures, rural and urban composts and vermicompost.

Unit VI

Biofertilizers–definition, classification, specifications, method of production and role in crop production; FCO specifications and quality control of biofertilizers.

Unit VII

Biological indicators of soil quality; bioremediation of contaminated soils; microbial transformations of heavy metals in soil; role of soil organisms in pedogenesis – important mechanisms and controlling factors; soil genomics and bioprospecting; soil sickness due to biological agents; xenobiotics; antibiotic production in soil.

VI. Practical

- Determination of soil microbial population
- Soil microbial biomass carbon
- Elemental composition, fractionation of organic matter and functional groups
- Decomposition of organic matter in soil
- Soil enzymes
- Measurement of important soil microbial processes such as ammonification, nitrification, N_2 fixation, S oxidation, P solubilization and mineralization of other micronutrients

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil microbes and their utility in research for s olving field problem.

IX. Suggested Reading

- Paul EA and Clark FE. *Soil Microbiology and Biochemistry*.
- Lynch JM. *Soil Biotechnology*
- Willey JM, Linda M. Sherwood and Woolverton CJ. *Prescott's Microbiology*.
- Subba Rao NS. *Advances In Agricultural Microbiology*.

I. Course Title : Radioisotopes in Soil and Plant Studies
II. Course Code : Soil 507
III. Credit Hours : 1+1

IV. **Aim of the course**

To train students in the use of radio isotopes in soil and plant research.

V. **Theory**

Unit I

Atomic structure, radio activity and units; radio isotopes-properties and decay principles; nature and properties of nuclear radiations; interaction of nuclear radiations with matter, artificial radioactivity

Unit II

Principles and use of radiation monitoring instruments-proportional, Geiger Muller counter, solid and liquids scintillation counters; neutron moisture meter, mass spectrometry, autoradiography

Unit III

Isotopic dilution techniques used in soil and plant research; use of stable isotopes; application of isotopes in studies on organic matter, nutrient transformations, ion transport, rooting pattern and fertilizer use efficiency; carbon dating

Unit IV

Doses of radiation exposure, radiation safety aspects regulatory aspects, collection, storage and disposal of radioactive wastes

VI. **Practical**

- Storage and handling of radioactive materials
- Determination of half-life and decay constant
- Preparation of soil and plant samples for radioactive measurements
- Setting up of experiment on fertilizer use efficiency and cation exchange equilibria using radio isotopes
- Determination of A, E and L values of soil using 32P/65Zn
- Use of neutron probe for moisture determination
- Sample preparation and measurement of 15N enrichment by mass spectro photometry/ emission spectrometry

VII. **Teaching methods/ activities**

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. **Learning outcome**

Experience on the knowledge of radio activity and their utility in research for solving field problems.

IX. Suggested Reading

- Comer CL. 1955. *Radioisotopes in Biology and Agriculture: Principles and Practice*. Tata McGraw Hill.
- Glasstone S. 1967. *Source Book on Atomic Energy*. East West Press.
- Michael FL and Annunziata. 2003. *Handbook of Radioactivity Analysis*. Academic Press.

I. Course Title : Soil, Water and Air Pollution

II. Course Code : Soil 508

III. Credit Hours : 2+1

IV. Aim of the course

To make the student saw are of the problems of soil, water and air pollution associated with use of soils for crop production.

V. Theory

Unit I

Soil, water and air pollution problems associated with agriculture, nature and extent.

Unit II

Nature and sources of pollutants – agricultural, industrial, urban wastes, fertilizers and pesticides, acid rains, oil spills etc.; air, water and soil pollutants- their CPC standards and effect on plants, animals and human beings.

Unit III

Sewage and industrial effluents–their composition and effect on soil properties/ health, and plant growth and human beings; soil as sink for waste disposal.

Unit IV

Pesticides–their classification, behaviour in soil and effect on soil microorganisms.

Unit V

Toxic elements–their sources, behaviour in soils, effect on nutrients availability, effect on plant and human health.

Unit VI

Pollution of water resources due to leaching of nutrients and pesticides from soil; emission of greenhouse gases–carbon dioxide, methane and nitrous oxide.

Unit VII

Risk assessment of polluted soil, Remediation/ amelioration of contaminated soil and water; remote sensing applications in monitoring and management of soil and water pollution.

VI. Practical

Sampling of sewage waters, sewage sludge, solid/ liquid industrial wastes, polluted soils and plants and their processing, Estimation of dissolved and suspended solids, chemical oxygen demand (COD), biological demand (BOD), measurement of coliform (MPN), nitrate and ammoniacal nitrogen and phosphorus, heavy metal content in effluents, Heavy metals in contaminated soils and plants, Management of contaminants in soil and plants to safe guard food safety, Air sampling and determination of particulate matter and oxides of sulphur, NO_2 and O_2 conc**.** Visit to various industrial sites to study the impact of pollutants on soil and plants.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Management of soil and water pollution

IX. Suggested Reading

- Lal R, Kimble J, Levine E and Stewart BA. 1995. *Soil Management and Greenhouse Effect.* CRC Press.
- Middlebrooks EJ. 1979. *Industrial Pollution Control*. Vol. I. *Agro-Industries*. John Wiley Interscience.
- Ross SM. *Toxic Metals in Soil Plant Systems*. John Wiley & Sons.
- Vesilund PA and Pierce 1983. *Environmental Pollution and Control*. Ann Arbor Science Publ.

I. Course Title: Remote Sensing and GIS Technique for Soil, Water and Crop Studies

II. Course Code : Soil 509

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about the basic concepts of remote sensing, aerial photographs and imageries, and their interpretation; application of remote sensing in general and with special reference to soil, plants and yield forecasting; to impart knowledge about geo-statistical techniques with special reference to krigging, and GIS and applicationsin agriculture.

V. Theory

Unit I

Introduction and history of remote sensing; sources, propagation of radiations in atmosphere; interactions with matter, basic concepts and principles; hardware and software requirements; common terminologies of geographic information system (GIS).

Unit II

Sensor systems-camera, microwave radio meters and scanners; fundamentals of aerial photographs and multispectral imaging, hyperspectral imaging, thermal imaging; image processing and interpretations.

Unit III

Application of remote sensing techniques-land use soil surveys, crop stress and yield forecasting, prioritization in watershed and drought management, waste land identification and management.

Unit IV

Significance and sources of the spatial and temporal variability in soils; variability in relation to size of sampling; classical and geo-statistical techniques of evolution of soil variability.

Unit V

Applications of GIS for water resources, agriculture, precision farming, disaster management, e-governance, Agricultural Research Information System (ARIS).

VI. Practical

Familiarization with different remote sensing equipments and data products, Interpretation of aerial photo graphs and satellite data for mapping of land resources, Analysis of variability of different soil properties with classical and geostatistical techniques, Creation of datafiles in a database programme, Use of GIS for soil spatial simulation and analysis, To enable the students to conduct soil survey and interpret soil survey reports in terms of land use planning.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and their utility in research for solving field problem.

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.

- Elangovan K. 2006. *GIS Fundamentals, Applications and Implementations*. New India Publ. Agency.
- Lillesand TM and Kiefer RW. 1994. *Remote Sensing and Image Interpretation*. 3rd Ed. Wiley.
- Nielsen DR and Wendroth O. 2003. *Spatial and Temporal Statis*tics. Catena Verloggmbh.
- Star J and Esles J. 1990. *Geographic Information System: An Introduction*. Prentice Hall.

I. Course Title : Analytical Technique and Instrumental Methods in Soil and Plant Analysis

I. Course Code : Soil 510

II. Credit Hours : 0+2

III. Aim of the course

To familiarize the students with commonly used instruments – their working, preparations of common analytical reagents for qualitative and quantitative analysis of both soil as well as plant samples.

IV. Practical

Unit I

Preparation of solutions for standard curves, indicators and standard solutions for acid-base, oxidation reduction and complexometric titration; soil, water andplant sampling techniques, their processing and handling.

Unit II

Determination of nutrient potentials and potential buffering capacities of soils for phosphorus and potassium; estimation of phosphorus, ammonium and potassium fixation capacities of soils.

Unit III

Principles of visible, ultra violet and infrared spectrophotometry, atomic absorption, flame-photometry, inductively coupled plasma spectrometry; chromatographic techniques, mass spectrometry and X-ray defractrometry; identification of minerals by X-ray by different methods, CHNS analyzer.

Unit IV

Electrochemical titration of clays; estimation of exchangeable cations (Na, Ca, Mg, K); estimation of root cation exchange capacity.

Unit V

Wet digestion/fusion/extraction of soil with aquaregia with soil for elemental analysis; triacid/di-acid digestion of plant samples; determination of available and total nutrients (N, P, K, S, Ca, Mg, Zn, Cu, Fe, Mn, B, Mo) in soils; determination of total nutrients (N, P, K, S, Ca, Mg, Zn, Cu, Fe, Mn, B, Mo) in plants

Unit VI

Drawing normalized exchange isotherms; measurement of redox potential.

V. Teaching methods/activities

Classroom teaching and laboratory practicals

VI. Learning outcome

Development of confidence for setting soil testing laboratory.

VII. Suggested Reading

- Hesse P. 971. *Textbook of Soil Chemical Analysis*. William Clowes & Sons.
- Jackson ML. 1967. *Soil Chemical Analysis*. Prentice Hall of India.
- Keith A Smith 1991. *Soil Analysis; Modern Instrumental Techniques*. Marcel Dekker.
- Kenneth Helrich 1990. *Official Methods of Analysis*. Association of Official Analytical Chemists.
- Page AL, Miller RH and Keeney DR. 1982. *Methods of Soil Analysis*. Part II. SSSA, Madison.
- Piper CE. *Soil and Plant Analysis*. Hans Publ.
- Singh D, Chhonkar PK and Pandey RN. 1999. *Soil Plant Water Analysis - A Methods Manual*. IARI, New Delhi.
- Tan KH. 2003. *Soil Sampling, Preparation and Analysis*. CRC Press/Taylor & Francis.
- Tandon HLS. 1993. *Methods of Analysis of Soils, Fertilizers and Wat*ers. FDCO, New Delhi.
- Vogel AL. 1979. *A Textbook of Quantitative Inorganic Analysis*. ELBS Longman.

I. Course Title : Management of Problem Soils and Water
II. Course Code : Soil 511
III. Credit Hours : 2+1

IV. Aim of the course

To educate students about basic concepts of problem soils and brackish water, and their management. Attention will be on management of problem soils and safe use of brackish water in relation to crop production.

V. Theory

Unit I

Area and distribution of problem soils–acidic, saline, sodic and physically degraded soils; origin and basic concept of problematic soils, and factors responsible.

Unit II

Morphological features of saline, sodic and saline-sodic soils; characterization of salt-affected soils-soluble salts, ESP, pH; physical, chemical and microbiological properties.

Unit III

Management of salt-affected soils; salt tolerance of crops- mechanism and ratings; salt stress meaning and its effect on crop growth, monitoring of soil salinity in the field; management principles for sandy, clayey, red lateritic and dryland soils.

Unit IV

Acid soils-nature of soil acidity, sources of soil acidity; effect on plant growth, lime requirement of acid soils; management of acid soils; biological sickness of soils and its management.

Unit V

Quality of irrigation water; management of brackish water for irrigation; salt balance under irrigation; characterization of brackish waters, area and extent; relationship in water use and quality.

Unit VI

Agronomic practices in relation to problematic soils; cropping pattern for utilizing poor quality groundwaters.

VI. Practical

Characterization of acid, acid sulfate, salt-affected and calcareous soils, Determination of cations (Na^+, K^+, Ca^{++} and Mg^{++}) in groundwater and soil samples, Determination of an ions (Cl^-, SO_4^-, CO_3^- and HCO_{3-}) in groundwaters and soil samples, Lime and gypsum requirements of acid and sodic soils.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on solving field problem of problem soil and waters.

IX. Resources

- Bear FE. 1964. *Chemistry of the Soil*. Oxford & IBH.
- Jurinak JJ. 1978. *Salt-affected Soils*. Department of Soil Science & Biometeorology. Utah State University
- USDA Handbook No. 60. 1954. *Diagnosis and improvement of Saline and Alkali Soils*. Oxford & IBH.

I. Course Title : Land Degradation and Restoration
II. Course Code : Soil 512
III. Credit Hours : 1+0

IV. Aim of the course

To impart knowledge related to various factors and processes of land degradation and their restoration techniques.

V. Theory

Unit I

Type, factors and processes of soil/land degradation and its impact on soil productivity including soil fauna, biodegradation and environment.

Unit II

Land restoration and conservation techniques-erosion control, reclamation of salt- affected soils; mine land reclamation, afforestation, organic products.

Unit III

Extent, diagnosis and mapping of land degradation by conventional and modern RS-GIS tools; monitoring land degradation by fast assessment, modern tools, land use policy, incentives and participatory approach for reversing land degradation; global issues for twenty first century.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on restoration of degraded soil for optimization of crop yield.

VIII. Suggested Reading

- Biswas TD and Narayanasamy G. (Eds.). 1996. *Soil Management in Relation to Land Degradation and Environment*. Bull. Indian Soc. Soil Sci. 17, New Delhi.

- Doran JW and Jones AJ. 1996. *Methods of Assessing Soil Quality*. Soil Science Society of America, Madison.
- Greenland DJ and Szabolcs I. 1994. *Soil Resilience and Sustainable Land Use*. CABI.
- Lal R, Blum WEH, Vailentine C and Stewart BA. 1997. *Methods for Assessment of Soil Degradation.* CRC Press.
- Sehgal J and Abrol IP. 1994. *Soil Degradation in India - Status and Impact*. Oxford & IBH.

I. Course Title : Soil Survey and Land Use Planning

II. Course Code : Soil 513

III. Credit Hours : 2+0

IV. Aim of the course

To teach the better utilization of land for agricultural purposes, and better management of run-off or surplus/ excessive rain-water in the catchment area for agricultural purposes in a watershed.

V. Theory

Unit I

Soil survey and its types; soil survey techniques- conventional and modern; soil series–characterization and procedure for establishing soil series; benchmarksoils and soil correlations; soil survey interpretations; thematic soil maps, cartography, mapping units, techniques for gene ration of soil maps, application of remote sensing and GIS in soil survey and mapping of major soil group of India

Unit II

Landform–soil relationship; major soil groups of India with special reference to respective states; land capability classification and land irrigability classification; land evaluation and land use type (LUT)–concept and application; approaches for managing soils and landscapes in the framework of agro-ecosystem.

Unit III

Concept and techniques of land use planning; factors governing present land use; Land evaluation method sand soil-site suitability evaluation for different crops; land capability classification and constraints in application.

Unit IV

Agro-ecological regions/sub-regions of India and their characteristics in relation to crop production. Status of LUP in India.

VI. Practical

- Aerial photo and satellite data interpretation for soil and land use
- Cartographic techniques for preparation of base maps and thematic maps, processing of field sheets, compilation and obstruction of maps in different scales
- Land use planning exercises using conventional and RS tools

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field visit and exposure visit.

VIII. Learning outcome

Planning for land use in proper way for higher crop productivity.

IX. Suggested Reading

- Boul SW, Hole ED, MacCraken RJ and Southard RJ. 1997. *Soil Genesis and Classification.*
- 4th Ed. Panima Publ.
- Brewer R. 1976. *Fabric and Mineral Analysis of Soils.* John Wiley & Sons.

I. Course Title : Introduction to Nanotechnology
II. Course Code : Soil 514
III. Credit Hours : 2+1

IV. Aim of the course

To impart basic knowledge about nanoscience, properties of nanoparticles and their applications in biology

V. Theory

Unit I

General introduction: Basics of quantum mechanics, harmonic oscillator,magnetic phenomena, band structure in solids, Mössbauer effect and spectroscopy, optical phenomena, bond in solids, an isotropy.

Unit II

Nanostructures: growth of compound semiconductors, super lattices, self-assembled quantum dots, nano-particles, nano tubes and nanowires, fullerenes (buck balls, graphene). Nanofabrication and nano-patterning: Optical, X-ray, and electron beam lithography, self-assembled organic layers, process of synthesis of nano powders, electrode position, important nanomaterials.

Unit III

Mechanical properties, magnetic properties, electrical properties, electronic conduction with nanoparticles, investigating and manipulating materials in the nanoscale: Electron microscopy

Unit IV

Nano-biology: Interaction between biomolecules and nano-particle surface, different types of in organic materials used for the synthesis of hybrid nano-bio assemblies, application of nano-in agriculture, current status of nano-biotechnology, future perspectives of nano-biology, nano-sensors.

VI. Practical

- Sources of nanoparticles and its preparation by different approaches
- Electrospinning and its use in agriculture and allied sector.
- Equipments used in Nanotechnology: its principle and uses
- Acquaintances with different equipments used in nanotechnology.
- Synthesis and characterization of Ag and ZnO nanoparticles.
- Mode of action of ZnO nanoparticles against soil borne diseases
- Study on efficacy of ZnO nanoparticles as seed treating agent on plant growth parameters.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of nano science and their utility in research for solving field problem.

IX. Suggested Reading

- Balandin AA and Wang KL. 2006. *Handbook of semiconductor nano structures and nano devices.* California: American Scientific Publishers.
- Timp G. 1999. *Nanotechnology*. New York: Springer Verlag.
- Challa Kumar SSR. 2006. *Nanotechnologies for the life sciences*. Weinheim: Wiley- VCHGmbH.
- Kohler M and Frintzsche W. 2007. *Nanotechnology: Introduction to nano structuring techniques* W Weinheim: Wiley-VCH Verlag GmbH.
- Kosal ME. 2009. *Nanotechnology for chemical and biological defense*. Dordrecht: Stringer.

SOIL 519 BASIC BIOCHEMISTRY 2+1

Objective

To provide elementary knowledge/overview of structure, functions and metabolism ofbiomolecules.

Theory

UNIT I

Scope and importance of biochemistry in agriculture; Fundamental principles governing life; structure of water; acid base concept and buffers; pH; hydrogenbonding; hydrophobic, electrostatic and Van der Waals forces; General introduction to physical techniques for determination of structure of biopolymers.

UNIT II

Classification, structure and function of carbohydrates, lipids and biomembranes, amino acids, proteins, and nucleic acids.

UNIT III

Structure and biological functions of vitamins, enzymes classification and mechanismof action; regulation, factors affecting enzyme action.

Fundamentals of thermodynamic principles applicable to biological processes, Bioenergetics.

UNIT IV

Metabolism of carbohydrates, photosynthesis and respiration, oxidative phosphorylation, lipids, proteins and nucleic acids. DNA replication, transcription and translation; recombinant DNA technology, Nutritional aspects of carbohydrates, lipids, proteins and minerals.

Practical

i. Preparation of standard and buffer solutions.
ii. Extraction and estimation of sugars and amino acids.
iii. Estimation of proteins by Lowry's method.
iv. Estimation of DNA and RNA by Diphenyamine and orcinol methods.
v. Estimation of ascorbic acid.
vi. Separation of biomolecules by TLC and paper chromatography

Suggested Readings

Conn EE & Stumpf PK. 1987. *Outlines of Biochemistry*. John Wiley.Metzler DE. *Biochemistry*. Vols. I, II. Wiley International.

Nelson DL & Cox MM. 2004. *Lehninger's Principles of Biochemistry*.MacMillan.

Voet D & Voet JG. *Biochemistry*. 3rd Ed. Wiley International.

Course Title with Credit Load for Ph D in Soil Science

Course Code	Course Title	Credit Hours
Soil 601	Recent trends in soil physics	2+0
Soil 602	Modern concept in soil fertility	2+0
Soil 603*	Physical chemistry of soil	2+0
Soil 604*	Soil genesis and micromorphology	2+0
Soil 605	Bio-chemistry of soil organic matter	2+0
Soil 606	Soil resource management	3+0
Soil 607	Modelling of soil plant system	2+0
Soil 608	Clay Mineralogy	2+1
Soil 609	Recent trends in soil microbial biodiversity	2+1
Soil 610	Research and Publication Ethics	2+0
Soil 691	Doctoral seminar -I	0+1
Soil 692	Doctoral seminar -II	0+1
Soil 699	Doctoral Research	0+75

*Indicates Core Courses which are Compulsory for PhD Programme

I. **Course Title** : **Recent Trends in Soil Physics**
II. **Course Code** : **Soil 601**
III. **Credit Hours** : **2+0**
IV. **Aim of the course**

To provide knowledge of modern concept sin soil physics.

V. **Theory**

Unit I

Soil-water interactions, soil water potential, free energy and thermodynamic basis of potential concept, chemical potential of soil water and entropy of the system, soil-plant-atmospheric continuum (SPAC).

Unit II

Fundamentals of fluid flow, Poiseuilles law, Laplace's equation, Darcy's law in saturated and unsaturated flows; development of differential equations in saturated and unsaturated water flow, capillary conductivity and diffusivity; limitations of Darcy's law; numerical solution for one dimensional water flow.

Unit III

Theories of horizontal and vertical infiltration under different boundary conditions.

Unit IV

Movement of salts in soils, models for miscible-immiscible displacement, diffusion, mass flow and dispersion of solutes and their solutions through differential equations; break-through curves.

Unit V

Soil air and aeration, mass flow and diffusion processes; thermal properties of soil, heat transfer in soils, differential equation of heat flow, measurement of thermal conductivity of soil; Soil, Plant, Water relations- Plant uptake of soil moisture, Water balance and energy balance in the field; irrigation and water use efficiency.

Unit VI

Soil crust and clod formation; structural management of puddled rice soils; soil conditioning-concept, soils conditioners-types, characteristics, working principles, significance in agriculture.

Unit VII

Solar and terrestrial radiation measurement, dissipation and distribution in soil-crop systems; prediction of evapotranspiration using aerodynamic and canopy temperature-based models; canopy temperature and leaf diffusion resistance in relation to plant water deficit; evaluation of soil and plant water status using infra- red thermometer.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

VIII. Suggested Reading

- Baver LD, Gardner WH and Gardner WR. 1972. *Soil Physics*. John Wiley & Sons.
- Hanks and Ascheroft. 1980. *Applied Soil Physics*. Springer Verlag.
- Hillel D. 1980. *Applications of Soil Physics*. Academic Press.
- Hillel D. 1980. *Environmental Soil Physic*s. Academic Press.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Kirkham D and Powers WL. 1972. *Advanced Soil Physics*. Wiley Interscience.
- Lal R and Shukla MK. 2004. *Principles of Soil Physics*. Marcel Dekker.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. Course Title : Modern Concept in Soil Fertility
II. Course Code : Soil 602
III. Credit Hours : 2+0
IV. Aim of the course

To provide knowledge of modern concepts of soil fertility and nutrient use in crop production.

V. Theory

Unit I

Nutrient availability-concept and relationships, modern concepts of nutrient availability; soil colloids and nutrient availability; soil amendments and availability maintenance of nutrients, soil solution and plant growth; nutrient response functions and availability indices.

Unit II

Nutrient movement in soils; nutrient absorption by plants; mechanistic approach to nutrient supply and uptake by plants; models for transformation and movement of major micronutrients in soils.

Unit III

Chemical equilibria (including solid-solution equilibria) involving nutrient ions in soils, particularly in submerged soils; Kinetic studies of nutrients in soils.

Unit IV

Modern concepts of fertilizer evaluation, nutrient use efficiency and nutrient budgeting.

Unit V

Modern concepts in fertilizer application; soil fertility evaluation techniques; role of soil tests in fertilizer use recommendations; site-specific nutrient management for precision agriculture.

Unit VI

Monitoring physical, chemical and biological changes in soils; permanent manurial trials and long-term fertilizer experiments; soil productivity under long-term intensive cropping; direct, residual and cumulative effect of fertilizer use.

Unit VII

Carbon– a nutrient central to soil fertility; carbon cycle in nature, stocks, pools and fluxes; greenhouse effect and climate change; carbon sequestration vis-à- vis-sustenance of soil quality and crop productivity.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil fertility and fertilizers in relation to plant growth and development.

VIII. Suggested Reading

- Barber SA. 1995. *Soil Nutrient Bioavailability*. John Wiley & Sons.
- Barker V Allen and Pilbeam David J. 2007. *Handbook of Plant Nutrition*. CRC / Taylor & Francis.
- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Educ.
- Cooke GW. 1979. *The Control of Soil Fertility*. Crossby Lockwood & Sons.
- Epstein E. 1987. *Mineral Nutrition of Plants - Principles and Perspectives*. International Potash Institute, Switzerland.
- Kabata- Pendias Alina 2001. *Trace Elements in Soils and Plants*. CRC / Taylor & Francis.

- Kannaiyan S, Kumar K and Govindarajan K. 2004. *Biofertilizers Technolo*gy. Scientific Publ.
- Mortvedt JJ, Shuman LM, Cox FR and Welch RM. (Eds.). 1991. *Micronutrients in Agriculture*. 2nd Ed. Soil Science Society of America, Madison.
- Prasad R and Power JF. 1997. *Soil Fertility Management for Sustainable Agriculture*. CRC Press.
- Stevenson FJ and Cole MA. 1999. *Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulphur, Micronutrients.* John Wiley & Sons.
- Stevenson FJ. (Ed.). 1982. *Nitrogen in Agricultural Soils*. Soil Science Society of America, Madison.
- Tisdale SL, Nelson WL, Beaton JD and Havlin JL. 1990. *Soil Fertility and Fertilizers.* 5th Ed. Macmillan Publ.
- Wild A. (Ed.). 1988. *Russell's Soil Conditions and Plant Growth*. 11th Ed. Longman.

I. Course Title : Physical Chemistry of Soil

II. Course Code : Soil 603

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge about modern concepts of physical chemistry of soils and clays, with emphasis on understanding the processes involved with practical significance.

V. Theory

Unit I

Colloidal chemistry of inorganic and organic components of soils–their formation, clay organic interaction.

Unit II

Predictive approaches for cation exchange equilibria- thermodynamics, empirical and diffuse double layer theory (DDL)- relationships among different selectivity coefficients; structure and properties of diffuse double layer.

Unit III

Thermodynamics of nutrient transformations in soils; Climate change effects on minerology and surface properties of variable charge; cationic and anionic exchange and their models, molecular interaction.

Unit IV

Adsorption/desorption isotherms-Langmuir adsorption isotherm, Freundlich adsorption isotherm, normalized exchange isotherm, BET equation; selective and non-selective adsorption of ions on in organic surfaces and organic surfacesof soil materials (citation of utility in agricultural system).

Unit V

Common solubility equilibria-carbonates, iron oxide and hydroxides, aluminum silicate, aluminum phosphate; electrochemical properties of clays (citation of examples from agricultural use).

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil chemical behaviour on research for solving field problems.

VIII. Suggested Reading

- Bear RE. 1964. *Chemistry of the Soil.* Oxford & IBH.
- Bolt GH and Bruggenwert MGM. 1978. *Soil Chemistry*. Elsevier.
- Fried M and Broeshart H. 1967. *Soil Plant System in Relation to Inorganic Nutrition.* Academic Press.
- Greenland DJ and Hayes MHB. 1981. *Chemistry of Soil Processes*. John Wiley & Sons.
- Greenland DJ and Hayes MHB. 1978. *Chemistry of Soil Constituents*. John Wiley & Sons.
- Jurinak JJ. 1978. *Chemistry of Aquatic Systems*. Department of Soil Science and Biometeorology, Utah State University
- McBride MB. 1994. *Environmental Chemistry of Soils.* Oxford University Press.
- Sparks DL. 1999. *Soil Physical Chemistry*. 2nd Ed. CRC Press.
- Sposito G. 1981. *The Thermodynamics of Soil Solutions*. Oxford University Press.
- Sposito G. 1984. *The Surface Chemistry of Soils*. Oxford University Press.
- Sposito G. 1989. *The Chemistry of Soils*. Oxford University Press.
- Stevenson FJ. 1994. *Humus Chemistry*. 2nd Ed. John Wiley.
- van Olphan H. 1977. *Introduction to Clay Colloid Chemistry*. John Wiley & Sons.

I. **Course Title** : **Soil Genesis and Micromorphology**

II. **Course Code** : **Soil 604**

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

IV. **Aim of the course**

To impart knowledge about the pedogenic processes in soils and to acquaint with the micro-pedological study of soil profile.

V. **Theory**

Unit I

Pedogenic evolution of soils; soil composition and characterization.

Unit II

Weathering and soil formation–factors and pedogenic processes; stability and weathering sequences of minerals.

Unit III

Assessment of soil profile development by mineralogical and chemical analysis.

Unit IV

Micro-pedological features of soils–their structure, fabric analysis, role in genesis and classification.

VI. **Teaching methods/activities**

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. **Learning outcome**

Experience on the knowledge of soil micro pedology and soil taxonomy on research for solving field problems.

VIII. **Suggested Reading**

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- Buol EW, Hole ED, MacCracken RJ & Southard RJ. 1997. *Soil Genesis and Classification*. 4th Ed. Panima Publ.
- Dixon JB and Weed SB. 1989. *Minerals in Soil Environments*. 2nd Ed. Soil Science Society of America, Madison.
- Grim RE. 1968. *Clay Mineralogy*. McGraw Hill.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Sehgal J. 2002. *Introductory Pedology: Concepts and Applications*. New Delhi
- Sehgal J. 2002. *Pedology - Concepts and Applications*. Kalyani.

- USDA. 1999. *Soil Taxonomy*. Hand Book No**.** 436. 2nd Ed. USDA NRCS, Washington.
- Wade FA and Mattox RB. 1960. *Elements of Crystallography and Mineralogy*. Oxford & IBH.

I. Course Title : Biochemistry of Soil Organic Matter
II. Course Code : Soil 605
III. Credit Hours : 2+0
IV. Aim of the course

To impart knowledge related to chemistry and reactions of organic substances and their significance in soils.

V. Theory

Unit I

Organic matter in soils and its maintenance. Role of organic matter in soil productivity; humus levels in soils; current thinking on the maintenance of organic matter in the soils. Carbon retention and sequestration.

Unit II

Biochemistry of the humus formation; different pathways for humus synthesis in soil; soil carbohydrates and lipids.

Unit III

Nutrient transformation–N, P, S; trace metal interaction with humic substances, significance of chelation reactions in soils.

Unit IV

Reactive functional groups of humic substances, adsorption of organic compounds by clay and role of organic substances in pedogenic soil aggregation processes; clay- organic matter complexes.

Unit V

Humus-pesticide interactions in soil, mechanisms.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience problems on the knowledge of soil biochemistry on research for solving field

VIII. Reading Materials

- Lynch JM, Willey JM. *Soil Biotechnology*.
- Paul EA and Clark FE. *Soil Microbiology and Biochemistry*.

- Sherwood LM and Woolverton CJ. *Prescott's Microbiology*.
- Subba Rao NS. *Advances In Agricultural Microbiology.*

I. Course Title : Soil Resource Management
II. Course Code : Soil 606
III. Credit Hours : 3+0
IV. Aim of the course

To impart the students basic holistic knowledge on soil resource and latest developments in its sustainable use.

Unit I

Relevance of soil management to sustainable agriculture; soil as a natural resource for biomass production, filtering, buffering, transportation of solutes, gene reserves, and geogenic source of raw materials; soil as a source and sink of greenhouse gases.

Unit II

Concept of sustainable land management (SLM); spatial variability of soils; soil quality and food security; soil quality indices, conservation agriculture in relation to soil quality; soil resilience and resistance.

Unit III

Types, factors and causes of land degradation and desertification; GLASOD classification; application of GIS and remote sensing in monitoring, diagnosis and mapping land degradation; history, distribution, identification and description of soil erosion problems in India; forms of soil erosion; impact of soil erosion-on- site and off-site effects; strategies for erosion control and conservation; soil conservation in hilly, arid, semiarid, coastal and diaralands. Management of forest, peat and muck soils.

Unit IV

Soil conservation planning; land capability classification; soil conservation in special problem areas such as hilly, arid and semi-arid regions, waterlogged and wetlands; land restoration and conservation techniques–erosion control, reclamation of salt affected soils; mine land reclamation, afforestation, organic products, soil fauna and biodegradation.

Unit V

Watershed management-concept, objectives and approach; water harvesting and recycling; flood control in watershed management; socio-economic aspects of watershed management; case studies in respect to monitoring and evaluation of watersheds.

Unit VI

Agro-ecological regions of India; potentials and constraints of soils of different regions; land evaluation and rationalizing land use, decision support system with relation to land management; national and international soil policy considerations.

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VI. Learning outcome

Experience on the knowledge of soil resources on research for solving field problems.

VII. Suggested Reading

- Abrol IP and Dhruvanarayana VV. 1990. *Technology for Wasteland Development*. ICAR, New Delhi.
- Andriesse JP. 1988. *Nature and Management of Tropical Peat Soils*, Soil Resources, FAO Soils Bulletin 59, Management and Conservation Service, Land and Water Development Division, FAO, Rome
- Blackwell, Dent D and Young A. 1981. *Soil Survey and Land Evaluation*. George Allen and Unwin, London.
- Burrough A and McDonnell RK. 1998.*Principles of Geographical Information System*. Oxford University Press.
- Dan Binkley D and Fisher R. 2012. *Ecology and Management of Forest Soils*,4th Edition, Wiley.
- FAO. 1996. *Land Quality Indicators and their Use in Sustainable Agriculture and Rural Development*. FAO Land and Water Bulletin.5. FAO, Rome.
- Faroq M and Siddique K. (Ed.). 2015. *Conservation Agriculture*, Springer Nature, Chennai, India.
- FESL. 1993. *An International Framework for Evaluating Sustainable Land Management, FAO World Soil Resources Report No. 73*, Land Development Division, FAO, Rome.
- ISSS. 1994. *Management of Land and Water Resources for Sustainable Agriculture and Environment*. Diamond Jubilee Symposium Publication, Indian Society of Soil Science, New Delhi.
- Lal R, Blum WEH, Valentine C and Stewart BA. (Editors). 1988. *Methods for Assessment of Soil Degradation*. CRC Press, Boca Raton.
- Mulders MA. 1987. *Remote Sensing in Soil Science*. Elsevier Science Publishers, Amsterdam.
- Sehgal J. 2014. *A Text Book of Pedology Concepts and Application*.

Kalyani publishers, New Delhi.

- SSSA 1996. *Methods for Assessing Soil Quality*. SSSA Publication Number 49, Madison, Wisconsin, USA.

I. Course Title : Modelling of Soil Plant System

II. Course Code : Soil 607

III. Credit Hours : 2+0

IV. Aim of the course

To train the students in concepts, methodology, technology and use of systems simulation in soil and crop studies

V. Theory

Unit I

Introduction, terms and definitions; classification of models; Taylor series; numerical methods of differentiation and integration.

Unit II

High level computer language: FORTRAN-its commands and usage; testing and evaluation of model.

Unit III

Description of spatially homogeneous models; K transformation model; nitrogen and phosphorus dynamics in soil.

Unit IV

Spatially heterogeneous models; equation of continuity; Simulation of water flow through soil; Explicit and Explicit-Implicit method; simulation of solutemovement through soil with variable moisture flux by explicit-implicit method.

Unit V

Nutrient uptake model: Integration of nutrient movement in soil (mass flow and diffusion) and uptake by plants (Michaelis-Menten kinetics); Nutrient uptake model: Solubility and free ion activity model.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on soil modelling concept for forecasting productivity

VIII. Suggested Reading

- Datta SC. 2008. *Theory and Principles of Simulation Modeling in Soil-Plant System*. Capital Publishing Company, New Delhi.

- Frame J and Thornley JHM. 1984. *Mathematical Models in Agriculture—A Quantitative approach to problems in agriculture and related science*. Butterworth and Co. Ltd.
- Freud PJ and Minton PD. 1979. *Regression Methods—A tool for data Analysis*. Marcel Dekker
- Inc., New York.
- Frissel MJ and Reinger P. 1974. *Simulation of Accumulation and Leaching in Sils*. Oxford and IBM Pub. Co., New Delhi.
- Hanks J and Richie JT. (Eds.). 1991. *Modeling Plant and Soil System*. Agronomy Bulletin No. 31, ASA, SSSA Madison, Wisconsin, USA.
- Lipschutz S and Poe A. 1978. *Schaum's Outline Series–Theory and Problems of programming*
- *with Fortran*. McGraw-Hill Book Co., Singapore.
- Penning de Vries FWT, Jansen DM, Ten Berge HFM and Baker A. 1989. *Simulation of ecophysiological processes of growth in several annual crops*. PUDOC, Wageningen.
- Shaffer MJ, Ma L and Hansen S. 2001. *Modeling Carbon and Nitrogen Dynamics for Soil Management*. Lewis Publishers, Boca Raton.

I. Course Title : Clay Mineralogy
II. Course Code : Soil 608
III. Credit Hours : 2+1

IV. Theory

Unit I

Definition and concepts of clays and clay minerals, Fundamentals of Fundamentals of crystallography – unit cell, external characteristics of crystals, crystallographic notations, crystal systems.

Unit II

Structures and classification of silicate minerals, basics of phyllosilicates, laws governing structural characteristics of phyllosilicates, Goldschmitdt's laws – Laws I and Law II, Classification of Phyllosilicates.

Unit III

Kaolinite group of minerals, Dioctahedral kaolins and Trioctahedral kaolins.

Unit IV

Smectites; properties of smectites, Reference models of structure, principaltypes based on Hofmann-Marshal-Hendricks (H-M-H) models, occurrence of smectites, transformation and formation in soils.

Unit V

Micas: occurrence and origin in soils, polytypes of micas, structure and formation of muscovites and illite.

Unit VI

Vermicullites: structure, occurrence in soils, formation, relation between vermiculites and montmorillonite.

Unit VII

Chlorite: occurrence and structure of chlorites, “swelling chlorites”, formation of chlorite.

Unit VIII

Non-crystalline clays (amorphous materials), subgroups and chemical composition, morphology and structure, physico-chemical properties, influence of non-crystalline clays on soil properties.

Unit IX

Interstratified clay minerals, occurrence and formation in soils, regularly interstratified and partially random interstratified minerals.

Unit X

Genesis and transformation of clay minerals, Generalized conditions for formation and persistence of common clay-size minerals in soils.

Unit XI

Surface chemistry of clay minerals, clay-organic complexes, nanoclay mineralogy.

Unit XII

Clay minerals in different soil orders, role of clay minerals in soil fertility management.

V. Practicals

- Separation of clay for mineralogical study
- X-ray diffraction analysis of clay
- Selective dissolution of clay minerals
- IR, DTA and SEM of clay minerals
- Identification and quantification of clay minerals
- Determination of surface charge of clay minerals
- Potentiometric titration of clay minerals.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on soil clays and utility in soil research.

VIII. Suggested Reading

- Dixon JB and Weed SB (Co-editors). *Minerals in Soil Environment.*
- Gieseking JE (Ed). *Soil Component*, Vol. 2. Inorganic Components.
- Grim RE. *Clay Mineralogy*.
- Mukherjee SK and Biswas TD (Editors). *Mineralogy of Soil Clays and Clay Minerals.*
- Read HH. *Rutley's Elements of Mineralogy.*
- Wilding LP and Smeck NE. 1983. *Pedogenesis and Soil Taxonomy Part II – Soil Orders.*

I. Course Title : Recent Trends in Soil Microbial Biodiversity

II. Course Code : Soil 609

III. Credit Hours : 2+1

IV. Theory

Unit I

Microbial evaluation and biodiversity, Microbial communities in ecosystems, New insights in below ground diverse of plant performance.

Unit II

Qualitative ecology of microorganisms; Biomass and activities.

Unit III

Nitrogen fixing organisms, Trends in diversity of N fixing organisms. Molecular approaches in characterizing N fixing microorganisms.

Unit IV

Serology and molecular characterization, ecological aspects of bio determination, soil waste and water management

Unit V

Biodegradability, testing and monitoring of the bioremediation of xenobiotic pollutants and bacterial fertilizers

V. Practicals

- Determination of soil microbes using classical techniques.
- Determination of soil microbial diversity using molecular techniques.
- Estimation of soil microbial biomass carbon, nitrogen and phosphorus.

- Estimation of key soil enzyme activities.
- Community level physiological profiling of microbial diversity.

VI. Teaching methods/Activities

Classroom teaching with AV aids, group discussion, field visit

VII. Learning outcome

Experience on soil microbial diversity and planning for proper utilization.

VIII. Suggested Reading

- Lynch JM, Willey JM. *Soil Biotechnology*.
- Paul EA and Clark FE. *Soil Microbiology and Biochemistry*.
- Sherwood LM and Woolverton CJ. *Prescott's Microbiology*.
- Subba Rao NS. *Advances In Agricultural Microbiology*.

I. Course Title : Research and Publication Ethics
II. Course Code : Soil 610
III. Credit Hours : 2+0
IV. Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications,fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data.

Unit IV

Publication ethics: Definition, introduction and importance. Best practices/standard setting initiatives and guidelines: COPE, WAME, *etc*., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatory publishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to check publisher copy right and self archiving policies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools, viz., JANE, Elsevier Journal Finder, Springer Journal Suggester etc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open source software tools.

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, etc. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g index, i10 index altmetrics

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field, laboratory and library visit

VI. Learning outcome

Quality research output and outstanding research publication with excellent impact factor

AGRICULTURAL METEOROLOGY

Course Title with Credit Load for M.Sc. in Agricultural Meteorology

Course Code	Course Title	Credit Hours
AGM 501*	Fundamentals of Meteorology	2+1
AGM 502*	Fundamentals of Agricultural Meteorology	2+1
AGM 503	Crop-weather Relationships	2+0
AGM 504*	Agro-meteorological Measurements and Instrumentation	1+2
AGM 505	Crop Micrometeorology	2+1
AGM 506	Evapotranspiration and Soil Water Balance	2+1
AGM 507	Crop weather models	1+2
AGM 508	Applied Agricultural Climatology	1+2
AGM 509	Weather forecasting	2+1
AGM 510	RS and GIS Applications in Agricultural Meteorology	2+1
AGM 514	Strategic use of climatic information	2+1
AGM 515	Weather and climate risk management	2+0
AGM 516	Aerobiometeorology	2+1
AGM 591	Master’s Seminar	0+1
AGM 599	Master’s Research	0+30

*Indicates core courses for M.Sc.

I. **Course Title : Fundamentals of Meteorology**

II. **Course Code : AGM 501**

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

IV. **Aim of the course**

To impart theoretical and practical knowledge of physical processes occurring inatmosphere and techniques used in meteorology.

V. **Theory**

Unit I

Solar radiation and laws of radiation; greenhouse effect, albedo, and heat balance of the earth and atmosphere; variation in pressure and temperature with height, potential temperature, pressure gradient, cyclonic and anticyclonic motions; geostropic and gradient winds; equations of motion; general circulation, turbulence,vorticity, atmospheric waves.

Unit II

Gas laws, laws of thermodynamics and their application to atmosphere;water vapour in the atmosphere, various humidity parameters and their interrelationships; vapour pressure, psychrometric equation, saturation deficit, Lapse rates-ascent of dry and moist air, stability and instability conditions in the atmosphere.

Unit III

Agromet observatory and analysis of weather data; Condensation; clouds and their classification; evaporation and rainfall; the hydrological cycle; precipitation processes, artificial rainmaking, thunderstorms and dust storm; haze, mist, fog, and dew; air masses and fronts; tropical and extra-tropical cyclones.

Unit IV

Effect of Earth's rotation on zonal distribution of radiation, rainfall, temperature, and wind; the trade winds, equatorial trough and its movement;

Unit V

Monsoon and its origin; Indian monsoon and its seasonal aspects: Onset, advancement and retreat of monsoon in different parts of India, Walker and Hadleycell, El Nino, La Nina, Southern Oscillation Index and their impact on monsoon.

VI. **Practical**

- Agromet observatory- different classes of observatories (A, B, C)

- Site selection and installation procedures for meteorological instruments
- Measurement of weather parameters.
- Reading and recording, calculation of daily, weekly, monthly means.
- Totals of weather data.
- Weather chart preparation and identification of low pressure systems and ridges.
- Statistical technique for computation of climatic normals, moving average, etc.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

IX. Suggested Reading

- Ahrens. 2008. *Meteorology today*, 9th Edition. Wadsworth Publishing Co Inc.
- Barry RG and Richard JC. 2003. *Atmosphere, Weather and Climate*. Tailor & Fransics Group.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Ghadekar SR. 2001. *Meteorology*. Agromet Publishers (Nagpur).
- Ghadekar SR. 2002. *Practical Meteorology*. Agromet Publishers (Nagpur).
- Mcllveen R. 1992. *Fundamentals of Weather and Climate*. Chapman & Hall.
- Petterson S. 1958. *Introduction to Meteorology*. McGraw Hill.
- Trewartha Glenn T. 1954. *An Introduction to Climate*. McGraw Hill.
- Varshneya MC and Pillai PB. 2003. *Text Book of Agricultural Meteorology*. ICAR.

Journals

- *Mausam*
- *Journal of Agrometeorology*
- *Italian Journal of Agrometeorology*
- *Theoretical and Applied Climatology*

Websites

- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. **Course Title : Fundamentals of Agricultural Meteorology**

II. **Course Code : AGM 502**

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

IV. **Aim of the course**

To impart the theoretical and practical knowledge of physical processes occurringin relation to plant and atmosphere with advanced techniques.

V. **Theory**

Unit I

Meaning and scope of agricultural meteorology; components of agricultural meteorology; role and responsibilities of agricultural meteorologists.

Unit II

Importance of meteorological parameters in agriculture; efficiency of solar energy conversion into dry matter production; meteorological factors in photosynthesis, respiration and net assimilation; basic principles of water balance in ecosystems; soil-water balance models and water production functions.

Unit III

Crop weather calendars; weather forecasts for agriculture at short, medium and long range levels; agromet advisories, preparation, dissemination and economic impact analysis; use of satellite imageries in weather forecasting; synoptic charts and synoptic approach to weather forecasting.

Concept, definition, types of drought and their causes; prediction of drought; crop water stress index, crop stress detection; air pollution and its influence on vegetation, meteorological aspects of forest fires and their control.

Unit V

Climatic change, green house effect, CO_2 increase, global warming and their impact on agriculture; climate classification, agro-climatic zones and agro-ecological regions of India.

VI. **Practical**

- Preparation of crop weather calendars

- Development of simple regression models for weather, pest and disease relation indifferent crops.
- Preparation of weather based agro-advisories
- Use of automated weather station (AWS)

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Overall and basic knowledge on Agrometeorology

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Kakde JR. 1985. *Agricultural Climatology.* Metropolitan Book Co.
- Mahi and Kingra. 2014. *Fundamentals of agrometeorology*. Kalyani publishers.
- Mavi HS and Tupper. 2004. *Principles and applications of climate studies in agriculture*. CRC Press
- Varshneya MC and Pillai PB. 2003. *Text Book of Agricultural Meteorology*. ICAR.

Journals

- *Journal of Agrometeorology*
- *Italian Journal of Agrometeorology*
- *Agricultural and Forest Meteorology*
- *Current Science*

Websites

- http://www.imd.gov.in/pages/main.php
- http://www.fao.org/home/en/
- www.wmo.org
- www.ipcc.org

I.	**Course Title**	**:**	**Crop-weather Relationships**
II.	**Course Code**	**:**	**AGM 503**
III.	**Credit Hours**	**:**	**2+0**

IV. Aim of the course

To study and understand the role of weather on crop growth and development.

V. Theory

Unit I

Understanding the influence of weather elements on crop growth, impact of natural and induced variability of climate on crop production.

Unit II

Climatic requirements of major crops, temperature effect on crop growth, radiation impact and radiation utlilization efficiency, humidity effect on crop performance, effect of soil temperature on seed germination and root growth, wind variation andcrop growth.

Unit III

Meteorological indices to predict crop production, Interpretation of weather forecasts for various agricultural operations towards improved productivity, crop-weather relationship in dryland areas. Crop weather relationship of major horticultural crops of the region and agroforestry system.

Unit IV

Rhizosphere and microorganisms in relation to weather, fertilizer and water use efficiency in relation to weather.

VI. Teaching methods/activities

Classroom teaching

VII. Learning outcome

To enhance the knowledge on intricate relationship between crop and weather.

VIII. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Jerry L. Hatfield, Mannava VK, Sivakumar and John H. Prueger. 2017. *Agroclimatology: Linking Agriculture to climate*. Agronomy Monographs 60.
- Mavi HS. 1994. *Introduction to Agrometeorology*. Oxford & IBH.
- Prasada Rao GSLHV. 2008. *Agricultural Meteorology*. PHI Learning Publishers.

Journals

- *Journal of Agrometeorology*
- *Agricultural and Forest Meteorology*

Websites

- http://www.imd.gov.in/pages/main.php
- http://www.fao.org/home/en/

I.	**Course Title**	**:**	**Agro-meteorological Measurements and Instrumentation**
II.	**Course Code**	**:**	**AGM 504**
III.	**Credit Hours**	**:**	**1+2**

Aim of the course

To impart the theoretical and practical knowledge of instruments/equipments usedfor measurement of agro-meteorological variables.

IV. Theory

Unit I

Fundamentals of measurement techniques; theory and working principles of barometer, thermometer, psychrometer, hair hygrometer, thermohygrograph; exposure and operation of meteorological instruments/ equipments in agromet observatories.

Unit II

Radiation and temperature measuring instruments: working principles of albedometer, photometer, spectro-radiometer, sunshine recorder, dew recorder, quantum radiation sensors, pressure bomb apparatus, thermographs, and infra-redthermometer.

Unit III

Precipitation and dew instruments: working principles of rain gauge, self recording rain gauge, Duvdevani dew gauges. Wind instruments: working principles of anemometer, wind vane, anemograph.

Unit IV

Evapotranspiration and photosynthesis instruments: working principles of lysimeters, open pan evaporimeters, porometer, photosynthesis system, leaf area meter.

Unit V

Boundary layer fluxes, Flux tower, soil heat flux plates, instruments to measuresoil moisture and soil temperature.

Unit VI

Automatic weather station – data logger and sensors, nano-sensors for measurementof weather variables; computation and interpretation of data.

V. Practical

- Working with the above instruments in the meteorological observatory, fields andlaboratory, Recording observations of relevant parameters.
- Computation and interpretation of the data.
- Analysis of AWS data.

VI. Teaching methods/activities

Mostly practical classes with demonstration and hands-on use of met-instruments

VII. Learning outcome

Practical classes and theory

VIII. Suggested Reading

- Anonymous. 1987. *Instructions to Observers at Surface Observatories*. Part I, IMD, New Delhi.
- Byers HR. 1959. *General Meteorology*. McGraw Hill.
- Ghadekar SR. 2002. *Practical Meteorology: Data Acquisition Techniques, Instruments and Methods*. Agromet Publ.
- Middleton WE and Spilhaws AF. 1962. *Meteorological Department*. University of Toronto Press.
- Tanner CB. 1973. *Basic Instrumentation and Measurements for Plant Environment and*

  Micrometeology. University of Wisconsin, Madison.
- WMO. 2008. *Guide to Meteorological Instruments and Methods of Observation*. WMO-No.8

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

https://public.wmo.int/en

I. **Course Title : Crop Micrometeorology**

II. **Course Code : AGM 505**

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

IV. **Aim of the course**

To impart the theoretical and practical knowledge of physical processes occurringin lower atmosphere and within crop canopy concerning crop growth.

V. **Theory**

Unit I

Properties of atmosphere near the Earth’s surface; exchange of mass momentum and energy between surface and overlaying atmosphere, exchange coefficient, similarity hypothesis, shearing stress, forced and free convection.

Unit II

Molecular and eddy transport of heat, water vapour and momentum, frictional effects, eddy diffusion, mixing; zero plane displacement, temperature instability, eddy covariance technique, microclimate near the bare ground, unstable and inversion layers, variation in microclimate under irrigated and rainfed conditions, soil moisture and temperature variation with depth; Richardson number, Raymondsanalogy, Exchange coefficients.

Unit III

Micrometeorology of plant canopies; distribution of temperature, humidity, vapour pressure, wind and carbon dioxide; modification of microclimate due to cultural practices, intercropping; radiation distribution and utilization by plant communities, leaf temperature and its biological effects; influence of topography on microclimate; shelter belts and wind breaks, microclimate in low plant area of meadows and grain fields, microclimate within forests, glass house and plastic house climates; instruments and measuring techniques in micrometeorology.

Unit IV

Effects of ambient weather conditions on growth, development and yield of crops; measurement of global and diffuse radiation; measurement of albedo over natural surfaces and cropped surfaces; net radiation measurement at different levels; PAR distribution in plant canopies and interception; wind, temperature and humidity profiles in (a) short crops and (b) tall crops; energy balance over crops and LAI and biomass estimation; remote sensing and its application in relation to micrometeorology.

VI. Practical

- Micrometerological measurements in crop canopies
- Quantification of crop microclimate
- Determination of ET and its computation by different methods.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

Knowledge of microclimatic conditions governing crop growth

IX. Suggested Reading

- Pal AS. 1988. *Introduction to Micrometeorology*. Academic Press.
- Bishnoi OP. 2007. Principles of Agricultural Meteorology. Oxford Book Co.
- Chang, Jen-Hu. 1968. *Climate and Agriculture: An Ecological Survey*. Aldine Publishing Company.
- Gates DM. 1968. *Energy Exchange in the Biosphere*. UNESCO.
- Goudriaan J. 1983. *Crop Micrometeorology: A Simulation Study*. Scientific Publ.
- Grace J. 1983. *Plant Atmospheric Relationships: Outline Studies in Ecology*. Chapman & Hall.
- Gupta PL and Rao VUM. 2000. *Practical Manual on Micrometeorology*. Dept. of Agril. Meteorology, CCS HAU Hisar, India.
- Jones HG. 1992. *Plants and Microclimate*. Cambridge Univ. Press. Munn RE. 1970.Biometeorological Methods. Academic Press.
- Monteith and Unsworth. 2013. *Principles of Environmental Physics*. Elsevier.
- Rosenberg NJ. 1974. *Microclimate – The biological Environmet*. John Wiley & Sons.
- Sellers W. 1967. *Physical Climatology*. The University of Chicago Press.

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

- https://public.wmo.int/en

I. **Course Title** : **Evapotranspiration and Soil Water Balance**

II. **Course Code** : **AGM 506**

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

IV. **Aim of the course**

To impart the theoretical and practical knowledge of ET estimation and determination of the components of soil water balance

V. **Theory**

Unit I

Energy concept of soil water, hydraulic conductivity and soil water flux; theory on hydraulic conductivity in saturated and unsaturated soils; physical factors concerning water movement in soil; concepts on evaporation, evapotranspiration, potentialand actual evapotranspiration.

Unit II

Theories of evapotranspiration and their comparison; aerodynamic, eddy correlation, energy balance, water balance and other methods, their application under different agroclimatic conditions; concepts of potential, reference and actual evapotranspiration - modified techniques.

Unit III

Influence of microclimatic and cultural factors on soil water balance; techniques of lysimetry in measuring actual evapotranspiration. water use efficiency and scheduling of irrigation based on evapotranspiration; water use efficiency and antitranspirants, computation of Kc values and their use; irrigation scheduling based on climatological approaches.

Yield functions; water use efficiency and scheduling of irrigation based on evapotranspiration; dry matter yield ET functions; radiation instruments; advanced techniques for measurement of radiation and energy balance; estimation of evapotranspiration through remote sensing.

VI. **Practical**

- Measurement of various components of soil water balance
- Evaluation of hydraulic conductivity vs. soil moisture relationship by water balance approach
- Computation and comparison of evapotranspiration by different methods - energy balance method, aerodynamic method, Penman method, remote sensing and other methods
- Soil moisture retention characteristics by pressure plate method.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

To know the estimation procedures and interlinkages among different components of field water balance.

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Burman R and Pochop LO. 1994. *Evaporation, Evapotranspiration and Climatic Data.* Elsevier.
- Grace J.1983. *Plant Atmospheric Relationships: Outline Studies in Ecology*. Chapman & Hall.
- Mavi HS and Tupper GJ. 2004. *Agrometeorology: Principles and Applications of Climate Studies in Agriculture*. The Haworth Press.
- Murthy VRK. 2002. *Basic Principles of Agricultural Meteorology*. BS Publ.
- Niwas R, Singh D and Rao VUM. 2000. *Pratical Manual on Evapotranspiration.* Dept. of Agril. Meteorology, CCS HAU Hisar.
- Rosenberg NJ, Blad BL and Verma SB. 1983. *Microclimate –The Biological Environment*. John Wiley & Sons.
- Subramaniam VP. 1982. *Water balance and its application*. Andhra University Press, Waltair, India.

Journals

- *Journal of Agrometeorology*
- *Archives of Agronomy and Soil Science*
- *Agricultural Water Management*
- *Journal of Hydrology*
- *Journal of Plant Ecology*

Websites

- https://www.icrisat.org/
- http://www.iwmi.cgiar.org/
- http://www.iiwm.res.in/

I. **Course Title : Crop Weather Models**

II. **Course Code : AGM 507**

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

IV. **Aim of the course**

To impart the theoretical and practical knowledge of various models for estimationof crop weather responses.

V. **Theory**

Unit I

Principles of crop production; effect of weather elements on crop responses; impactof natural and induced variability of climate on crop production.

Unit II

Introduction and application to crop modeling, types of models, Empirical and statistical crop weather models their application with examples; concept of crop growth model in relation to weather, soil, plant and other environmental related parameters and remote sensing inputs; growth and yield prediction models;

Unit III

Dynamic crop simulation models, e.g. DSSAT, InfoCrop, APSIM, CropSyst, etc.; optimization, calibration and validation of models. Weather data and physiology-based approaches to modeling of crop growth and yield; forecasting of pests and diseases; stochastic models; advantages and limitation of modeling.

VI. **Practical**

Working with statistical and simulation models, DSSAT models, InfoCrop, Oryza, etc.

VII. **Teaching methods/activities**

Theory and practical classes. Demonstration and hands-on practicals using crop models

VIII. **Learning outcome**

To utilize the crop weather model for observing weather influence on crop growth

IX. **Suggested Reading**

- Wallach D *et al*. *Working with dynamic crop models*.
- DeWit CT, Brouwer R and de Vries FWTP. 1970. *The Simulation of Photosynthetic Systems*. pp. 7-70. In. Prediction and Measurement of Photosynhetic Activity. Proc. Int. Biological Programme Plant Physiology Tech. Meeting Trebon PUDOC. Wageningen.

- Duncan WG. 1973. *SIMAI- A Model Simulating Growth and Yield in Corn*. In: The Application of Systems Methods to Crop Production (D.N. Baker, Ed.). Mississippi State Univ. Mississipi.
- Frere M and Popav G. 1979. *Agrometeorological Crop Monitoring and Forecasting.* FAO.
- Hanks RJ. 1974. *Model for Predicting Plant Yield as Influenced by Water Use*. Agron. J. 66: 660-665.
- Hay RKM and Porter JR. 2006. *The physiology of crop yield* (2nd Edition).
- Keulen H Van and Seligman NG. 1986. *Simulation of Water Use, Nitrogen Nutrition and Growth of a Spring Wheat Crop*. Simulation Monographs. PUDOC, Wageningen.
- Singh P. *Modelling of crop production systems: Principles and applications*.
- Weixing Cao *et al*. *Crop modeling and decision support.*

Journals

- *Journal of Agrometeorology*
- *Global Environmental Change*
- *Global Change Biology*
- *Mitigation and Adaptation Strategies for Global Change*

Websites

- https://www.apsim.info/
- https://dssat.net/

I. Course Title : Applied Agricultural Climatology

II. Course Code : AGM 508

III. Credit Hours : 1+2

IV. Aim of the course

To impart the theoretical and practical knowledge of computation of different bio-parameters and their applications in the agriculture.

V. Theory

Unit I

Climatic statistics: measures of central tendency and variability, skewness, kurtosis, homogeneity, correlation, regression and moving averages; probability analysis using normal, binomial, Markov-chain and incomplete gamma distribution; parametric and non parametric tests; assessment of frequency of disastrous events.

Unit II

Precipitation indices; Climatic water budget: potential and actual evapotranspiration and their computation; measurement of precipitation, calculation of water surplus and deficit; computation of daily and monthly water budget and their applications; assessment of dry and wet spells, available soil moisture, moisture adequacy index and their applications.

Unit III

Thermal indices and phenology: cardinal temperatures; heat unit and growing degree day concepts for crop phenology, crop growth and development; insect-pest development; crop weather calendars; agroclimatic requirement of crops.

Unit IV

Bioclimatic concepts: evaluation of human comfort, comfort indices (temperature, humidity index and wind chill) and clothing insulation; climate, housing and site orientation; climatic normals for animal production.

VI. Practical

- Use of statistical approaches in data analysis
- Preparation of climatic water budget
- Estimation of agro-meteorological variables using historical records
- Degree day concept and phenology forecasting and preparation of crop calendar
- Evaluation of radiation, wind and shading effects in site selection and orientation
- Study of weather-pest and disease interactions, calculation of continentality factors; calculation of comfort indices and preparation of climograph.

VII. Teaching methods/activities

Theory and practical classes knowledge on how to use the meteorological observations and derived indices areapplied in agricultural field

IX. Suggested Reading

- Anonymous 1980. *ICRISAT Climatic Classification – A Consultation Meeting*. ICRISAT.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Lal DS. 1989. *Climatology*. Chaitanya Publ. House.
- Mather JR. 1977. *Work Book in Applied Climatology*. Univ. of

Delware, New Jersey.

- Mavi HS and Tupper Graeme J. 2004. *Agrometeorology: Principles and Applications ofClimate Studies in Agriculture.* The Haworth Press.
- Stigter K (Ed.). 2010. *Applied Agrometeorology*. Springer
- Subramaniam VP. 1977. *Incidence and Spread of Continental Drought*. WMO/IMD Report No. 2, WMO, Geneva, Switzerland.
- Thompson R. 1997. *Applied Climatology: Principles and Practice*. Routledge.
- Walter J Saucier. 2003. *Principles of Meteorological Analysis*. Dover Phoenix Eds.

Journals

- *Theoretical and Applied Climatology*
- *Atmospheric Research Journal*
- *Journal of Agrometeorology*
- *Agricultural Climatology and Meteorology*
- *Journal of Applied Meteorology and Climatology*

Websites

- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. Course Title : Weather Forecasting

II. Course Code : AGM 509

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge of forecasting techniques used forweather prediction and preparation of agro-advisories.

V. Theory

Unit I

Weather forecasting system: definition, scope and importance; types of forecasting: short, medium and long-range; study of synoptic charts with special reference to location of highs and lows, jet streams, synoptic features and weather anomalies and zones of thermal advection and interpretation of satellite pictures of clouds in visible and infra-red range; weather forecasting network.

Unit II

Approaches for weather forecasts: methods of weather forecasts - synoptic, numerical prediction, statistical, analogue, persistence and climatological approach, nano- technological approach, Indigenous Technical Knowledge (ITK) base- signals from flora, fauna, insects, birds, animals behavior; various methods of verification of location-specific weather forecast.

Unit III

Special forecasts: special forecasts for natural calamities such as drought, floods, high winds, cold (frost) and heat waves, hail storms, cyclones and protection measures against such hazards.

Unit IV

Modification of weather hazards: weather modification for agriculture; scientific advances in artificial rain making, hail suppression, dissipation of fog and stratus clouds, modification of severe storms and electric behavior of clouds.

Unit V

Weather based advisories: interpretation of weather forecasts for soil moisture, farm operations, pest and disease development and epidemics, crops and livestock production; preparation of weather-based advisories and dissemination.

VI. Practical

- Exercise on weather forecasting for various applications
- Preparation of weather-based agro-advisories based on weather forecast using various approaches and synoptic charts.

VII. Teaching methods/ activities

Theory and practical classes

VIII. Learning outcome

Enhancing knowledge on weather forecast and its use

IX. Suggested Reading

- Watts A. 2005. *Instant Weather Forecasting*. Water Craft Books.
- Ram Sastry AA. 1984. *Weather and Weather Forecasting*. Publication Division, GOI, New Delhi.
- Singh SV, Rathore LS and Trivedi HKN. 1999. *A Guide for Agrometeorological Advisory*

  Services. Department of Science and Technology, NCMRWF, New Delhi.
- Wegman and Depriest. 1980. *Statistical Analysis of Weather Modification Experiments*. Amazon Book Co.

Journals

- *Journal of Climatology and Weather Forecasting*

- *Theoretical and Applied Climatology*
- *Atmospheric Research Journal*
- *Journal of Agrometeorology*
- *Agroclimatology*

Websites

- https://www.ipcc.ch/
- https://www.imd.gov.in/pages/main.php

I. Course Title : RS and GIS Applications in Agricultural Meteorology

II. Course Code : AGM 510

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of remote sensing principles andtheir use to estimate agro-meteorological variables.

V. Theory

Unit I

Basic components of remote sensing- signals, sensors and sensing systems; active and passive remote sensing.

Unit II

Characteristics of electromagnetic radiation and its interaction with matter; spectral features of earth's surface features; remote sensors in visible, infrared and microwave regions.

Unit III

Imaging and non-imaging systems; framing and scanning systems; resolution of sensors; sensor platforms, their launching and maintenance. Drone technology.

Unit IV

Data acquisition system, data preprocessing, storage and dissemination; digital image processing and information extraction.

Unit V

Microwave remote sensing; visual and digital image interpretation; introduction to GIS and GPS.

Unit VI

Digital techniques for crop discrimination and identification; crop stress detection - soil moisture assessment, inventory of ground water and satellite measurement of surface soil moisture and temperature; drought monitoring, monitoring of crop disease and pest infestation. Use of satellite data in weather forecasting.

Unit VII

Soil resource inventory; land use/land cover mapping and planning; integrated watershed development; crop yield modeling and crop production forecasting.

VI. Practical

- Acquisition of maps
- Field data collection
- Map and imagery scales
- S/W and H/W requirements and specifications for remote sensing
- Data products, their specifications, media types, data inputs, transformation, display types, image enhancement
- Image classification methods
- Evaluation of classification errors
- Crop discrimination and acreage estimations
- Differentiation of different degraded soils
- Time domain reflectometry
- Use of spectrometer and computation of vegetation indices
- Demonstration of case studies
- Hands on training

VII. Teaching methods/activities

Hands on practicals and theory

VIII. Learning outcome

Knowledge on RS-GIS technique for application in Agricultural Meteorology

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Campbell JB. 1996. *Introduction to Remote Sensing*, 2nd ed., The Guilford Press, New York.
- Colwell RN. (Ed.). *Manual of Remote Sensing*. Vols. 1, II. Am. Soc. Photogrammetry, Virginia.
- Curan PJ. *Principles of Remote Sensing.* ELBS/Longman.
- Georg Joseph 2005.*Fundamentals of Remote Sensing*. University Press (India).

- Jain AK. 1989. *Fundamentals of Digital Image Processing*, Prentice Hall of India.
- Lilisand TM, Kiefer RW and Chipman JW. 2003. *Remote Sensing and Image Interpretation*, 5th ed., John Wiley & Sons, Inc., New York.
- Narayan LRA. 1999. *Remote Sensing and its Applications*. Oscar Publ.
- Panda BC. 2008. *Principles and Applications of Remote Sensing*, Viva Publications.
- Patel AN and Surender Singh. 2004. *Remote Sensing: Principles and Applications*. Scientific Publ.

Journals

- *Journal of Global Environmental Change*
- *Journal of Remote Sensing and GIS*
- *Journal of Agrometeorology*

Websites

- https://www.nrsc.gov.in/
- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. **Course Title : Strategic Use of Climatic Information**

II. **Course Code : AGM 514**

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

IV. **Aim of the course**

To impart the theoretical and practical knowledge of climatic hazards and their mitigations.

V. **Theory**

Unit I

Increasing awareness on potential climate hazards and mitigations: history of climate-related disasters in the concerned continent/ region/ country/ sub-region and their documented or remembered impacts; Climatic hazards and extreme weather events (Cyclone, Hailstorm, drought, flood, etc.), Impact of climatic hazard on agricultural production; efforts made in mitigating impacts of (future) disasters (prevention); trends discernible in occurrence and character of disasters, if any.

Unit II

Selection of appropriate land use and cropping patterns: types and drivers of agricultural land use and cropping patterns based on climatic situation; history of present land use and cropping patterns in the sub-region concerned as related to environmental issues; successes and difficulties experienced by farmers with presentland use and cropping patterns; outlook for present land use and cropping patterns and possible alternatives from an environmental point of view.

Unit III

Adoption of preparedness strategies: priority settings for preparedness strategies in agricultural production; preparedness for meteorological disasters in development planning; permanent adaptation strategies that reduce the vulnerabilities to hazards;preparedness as a coping strategy.

Unit IV

Making more efficient use of agricultural inputs: agro-meteorological aspects of agricultural production inputs and their history; determination of input efficiencies based on weather conditions; other factors determining inputs and input efficiency; actual use of inputs in main land use and cropping patterns of the region.

Unit V

Adoption of microclimate modification techniques: review of microclimate management and manipulation methods; history of microclimate modification techniques practiced in the continent/ country/ sub-region concerned; possible improvements in adoption of microclimate modification techniques, given increasing climate variability and climate change; local trends in adoption of such techniques.

Unit VI

Protection measures against extreme climate: history of protection measures against extreme climate in the continent/ region/ country/ sub region concerned; successes and difficulties experienced by farmers with present protection measures; outlook for present protection measures and possible alternatives; trends in protection methods against extreme climate.

Practical

- Outlook for present land use and cropping patterns and possible alternatives fromenvironmental point of view
- Recent trends in land use and cropping patterns
- Agro-meteorological services to increase farmers design abilities of land use andcropping patterns
- Systematic and standardized data collection on protection measures againstextreme climate.

VI. **Teaching methods/activities**

Theory and practical classes

VII. **Learning outcome**

Application of climatic information for agriculture and natural resource management

VIII. **Suggested Reading**

- Anonymous. *Clean Development Mechanism: Building International Public-Private Partnership under Kyoto Protocol.* UNEP, UNDP Publ.
- Anonymous. *IPCC Assesment Reports on Climate Change Policy: Facts, Issues and Anlysis*. Cambridge Univ. Press.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Pretty J and Ball A. 2001. *Agricultural Influence on Carbon Emission and Sequestration: A Review of Evidence and the Emerging Trading Options*. Univ. of Essex.
- Pretty JN. 1995. *Regenerating Agriculture: Policies and Practices for Sustainable and Self Reliance*. Earthscan.

Journals

- *Climate Risk Management*, *Journal* of *Climate* (JCLI),
- *International Journal of Climatology*
- *Journal of Agrometeorology*

https://www.ncdc.noaa.gov/climate-information

I. **Course Title : Weather and Climate Risk Management**

II. **Course Code : AGM 515**

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

IV. **Aim of the course**

To impart the theoretical and practical knowledge of weather modification techniqueswith risk management strategies

V. **Theory**

Unit I

Risk characterization – definitions and classification of risks; characterization of weather and climate related risks in agriculture; water related risks; radiation/ heat related risks; air and its movement related risks;biomass related risks; social and economic risk factors related to weather and climate.

Unit II

Risks in agricultural production, history of weather and climate as accepted risk factors in agriculture in the continent/ region/ country/ sub-region concerned and the related documented risk concepts; preparedness for weather and climate risks.

Unit III

Risks of droughts; monitoring, prediction and prevention of drought; drought proofing and management; modern tools including remote sensing and GIS in monitoring and combating droughts.

Unit IV

Theories of weather modification; scientific advances in clouds and electrical behaviorof clouds; hails suppression, dissipation of fog, modification of frost intensity and severe storms; shelter belts and wind breaks, mulches and anti-transpirants; protection of plants against climatic hazards; air and water pollution; meteorological conditions in artificial and controlled climates - green, plastic, glass and animal houses, etc.

Unit V

Approaches and tools to deal with risks - history of methods for weather and climate related risk assessments in the continent/ region/ country/ subregion concerned and their documented evidence of application to agricultural/farming systems; strategies of dealing with risks- mitigating practices before occurrence; preparedness for the inevitable; contingency planning and responses; disaster risk mainstreaming.

Unit VI

Perspectives for farm applications - farm applications not yet dealt with, such as making risk information products more client friendly and transfer of risk information products to primary and secondary users of such information; heterogeneity of rural people in education, income, occupation and information demands and consequences for risk information products and their transfer; livelihood-focused support, participation and community perspectives; challenges for developing coping strategies including transferring risks through insurance schemes.

Unit VII

Challenges to coping strategies-combining challenges to disaster risk mainstreaming, mitigation practices, contingency planning and responses, basic preparedness; preparedness approaches reducing emergency relief necessities; the role that insurances can play in risk spreading and transfer;

application of methods that permit the incorporation of seasonal and long-term forecasts into the risk assessmentmodels.

VI. Teaching methods/ activities

Theory classes

VII. Learning outcome

Knowledge on different weather extremes and how to modify weather to reduce risk.

VIII. Suggested Reading

- Anonymous 2003. *Critical Issues in Weather Modification Research Board of Atmoshperic Science and Climate*. National Research Council, USA.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Chritchfield HJ. 1994. *General Climatology*. Prentice Hall.
- Lenka D. 1998. Climate, Weather and Crops in India. Kalyani.
- Mavi HS and Graeme J Tupper. 2004. *Agrometeorology: Principles and Applications ofClimate Studies in Agriculture*. The Haworth Press.
- Mavi HS. 1994. *Introduction to Agrometeorology*. Oxford & IBH.
- Menon PA. 1989. *Our Weather*. National Book Trust.
- Pearce RP. 2002. *Meteorology at the Millennium*. Academic Press.
- Rosenberg NJ, Blad BL and Verma SB. 1983. *Microclimate – The Biological Environment*. John Wiley & Sons.
- Samra JS, Narain P, Rattan RK and Singh SK. 2006. *Drought Management in India*. Bull. Indian Society of Soil Science 24, ISSS, New Delhi.

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

- https://www.icrisat.org/

I. Course Title : Aerobiometeorology
II. Course Code : AGM 516
III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical knowledge on insect, pest and plant biometeorology

V. **Theory**

Unit I

Definition and structure of Aerobiometeorology, role of Agrometeorology and Biogeography in forecasting pests and disease outbreak, insect movement in the atmosphere, intensification, Effect of weather and climate parameters on reproduction, growth, development, movements, food, habitat and dispersal of pests and diseases. Influence of weather and climate on Migratory pests (Desert locust, BPH etc.).

Unit II

Benevolent and malevolent weather conditions for salient pests & diseases of the

concerned agro-climatic zones. Effects of sudden weather changes and extreme

weather conditions on population built-up of the pest, heat stress and heat related mortality, climate change impact on pest and diseases.

Unit III

Biometeorology in integrated pest and disease management program, modification of plant canopy and its impact of plant diseases, management of segments of disease triangle: environment manipulation and host manipulation, weather based forewarning system for pest and diseases.

Unit IV

Soil borne pathogens, their biology, management and challenges, soil borne diseases and their control, abiotic factor in soil borne disease management, Managing of pests & diseases in controlled environment, Environmental management for pest and disease

VI. **Practical**

- Identification of different pests
- Pest population, observations and their index calculation
- Identification of various diseases
- Disease initiation and their intensity, percent disease index
- Relation between weather parameters and pests and disease

VII. **Teaching methods/activities**

Classroom teaching and practical, visit to fields

VIII. **Learning outcome**

Knowledge on interactions between atmospheric processes and living organisms, mainly pest and diseases

IX. Suggested Reading

- Yazdani, SS and Agarwal ML. 2002. *Elements of insect ecology*. Narosa Publishing House.
- Odum EP. *Fundamentals of insect ecology*.
- Dhaliwal GS and Arora R. *Integrated pest management*.
- Jerry L. Hatfield and Ivan J. Thomason. 1982. *Biometeorology in integrated pest management*, Academic press.

Journals

- *Aerobiologica*
- *Journal of Agrometeorology*
- *International Journal* of *Biometeorology*

Website

- http://www.imd.gov.in

Course Title with Credit Load for Ph.D in Agricultural Meteorology

Course Code	Course Title	Credit Hours
AGM601*	Climate change and sustainable development	2+1
AGM602	Meteorologyof air pollution	2+2
AGM603	Livestock and fisheries meteorology	2+2
AGM604	Hydrometeorology	2+1
AGM605	Analytical tools and methods for Agro-meteorology	1+1
AGM606	Research and publication ethics	2+0
AGM607	Weather and Climate Risk Management	3+0
AGM608*	Computer Programs and Software for Agrometeorological data Management	1+1
AGM691	Doctoral seminar I	0+1
AGM692	Doctoral seminar II	0+1
AGM699	Doctoral research	0+75

*Indicates core courses for PhD

I. **Course Title : Climate Change and Sustainable Development**

II. **Course Code : AGM 601**

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

IV. **Aim of the course**

To impart the theoretical and practical knowledge of climate change and the cause,effect, mitigation of climate change.

V. **Theory**

Unit I

Climate change and global warming: definitions of terms; causes of climate change and global warming; greenhouse gases, ozone depletion; past records, present trends, extreme weather events and future projections; Case studies on various climatic projections and consequences thereof in relation to agriculture.

Unit II

Impacts of climate change on various systems: impacts resulting from projected changes on agriculture and food security; hydrology and water resources; terrestrial and freshwater ecosystems; coastal zones and marine ecosystems; human health; human settlements, energy, and industry;insurance and other financial services; climate change and crop diversification, loss of biodiversity, microbes and pest dynamics; climatechange and storage, climate change and weed management. Advance methodology of assessing the impact of climate change on crops.

Unit III

Sensitivity, adaptation and vulnerability: system's sensitivity, adaptive capacity and vulnerability to climate change and extreme weather events; regional scenarios of climate change and variability.

Unit IV

Mitigation strategies for sustainable development: international policies, protocols, treaties for reduction in greenhouse gases and carbon emissions; carbon sequestration; carbon credit; Clean Development Mechanism (CDM) and land use, Crop management options for low emission, land use change and forestry mechanism, alternate energy sources, etc.

Unit V

Agricultural food security: reduction in carbon and GHG emission; fuel conservation and reduction in energy use, conservation tillage, biofuels for fossil fuels, reduction in machinery use etc; increasing carbon sinks; resource conservation technologies, mixed rotations of cover and green manure crops, minimization of summer fallowand no ground cover periods, etc.

VI. **Practical**

- Case studies on various climatic projections and consequences thereof in relationto agriculture
- Advance methodology of assessing the impact of climate change on crops

VII. **Teaching methods/ activities**

Classroom teaching, showing climatic models (GCMs and RCMs) though PPT, Handson practical

VIII. **Learning outcome**

Will be aware on causes, impacts, mitigation and adaptations to climate change in the field of agriculture

IX. **Suggested Reading**

- Anonymous. *Clean Development Mechanism: Building International Public-Private Partnership under Kyoto Protocol*. UNEP, UNDP Publ.
- Anonymous. *IPCC Assessment Reports on Climate Change* (2001, 2007). WMO, UNEP Publ.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Jepma CJ and Munasinghe M. 1998. *Climate Change Policy: Facts, Issues and Analysis*.Cambridge Univ. Press.
- Mintzer IM. 1992. *Confronting Climate Change: Risks, Implications and Responses*. Cambridge Univ. Press.
- Pretty J and Ball A. 2001. *Agricultural Influence on Carbon Emission and Sequestration: A Review of Evidence and the Emerging Trading Options*. Univ. of Essex.
- Pretty JN. 1995. *Regenerating Agriculture: Policies and Practices for Sustainable and Self Reliance*. Earthscan.
- Salinger J, Sivkumar MVK and Motha RP. 2005. *Increasing Climate Variability of Agricultureand Forestry*. Springer.
- Sinha SK. 1998. *Dictionary of Global Climate Change*. Commonwealth Publ.

Journal

- *Mitigation and Adaptation strategies for Global Change*
- *Climate Change*
- *Climate Risk Management*
- *Journal of Agrometeorology*

Website

- https://www.ipcc.ch/

- www.environment.gov.au/climate-change/climate-science-data/climate-science/ipcc

I. Course Title : Meteorology of Air Pollution
II. Course Code : AGM 602
III. Credit Hours : 2+2

IV. Aim of the course

To impart the theoretical and practical knowledge of air pollutants.

V. Theory

Unit I

Introduction to air pollution- history, definition: clean air definition; natural versus polluted atmosphere; atmosphere before the industrial revolution, Real time air quality index and National air quality index.

Unit II

Sources of air pollution; classification and properties of air pollutants; emission sources, importance of anthropogenic sources; behaviour and fate of air pollutants; photochemical smog; pollutants and trace gases. Acid rain and development of Gas Washing

Unit III

Meteorological factors in the dispersion of air pollutants; topographical, geographical and large scale meteorological factors attached air pollution; Planetary Boundary Layer (PBL) and mixing layer; meteorological conditions and typical plume forms; air pollution forecasting – Gaussian diffusion models, Numerical dispersion models.

Unit IV

Air quality standards; effect of air pollution on biological organisms; ozone layer depletion; air pollution control technologies; management of air pollution; principles of diffusion of particulate matter in the atmosphere; air pollution laws and standards. Scales of air pollution: local, urban, regional, continental and global.

Unit V

Air pollution sampling and measurement: types of pollutant sampling and measurement, ambient air sampling, collection of gaseous air pollutants, collection of particulate pollutants, stock sampling; analysis of air pollutants - sulfur dioxide, nitrogen dioxide, carbon monoxide, oxidants and ozone, hydrocarbons, particulate matter.

VI. Practicals

- Measurement of different air pollutants
- Measurement of different air pollution gases
- Measurement of visibility
- Measurement of ozone and aerosol optical thickness (AOT)
- To study the temperature profile at different heights
- To study the stability of the atmosphere
- To determine height of partial flume through chimani
- To study the effect of temperature on vegetables, orchards and agricultural crops

VII. Teaching methods/activities

Classroom teaching and practical

VIII. Learning outcome

Knowledge of sources and dispersal of pollutants,meteorological activities and analysis of pollutants

IX. Suggested Reading

Indexing, the influence of

- Arya SP. 1998. *Air Pollution Meteorology and Dispersion*. Oxford Univ. Press.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Chhatwa GR. 1989. *Environmental Air Pollution and its Control*. Anmol Publ.
- Mishra PC. 1990. *Fundamentals of Air and Water Pollution*. Ashish Publ.
- Mudd J Brian and Kozlowski TT. (Ed.). 1975. *Responses of Plants to Air Pollution*. Academic Press.
- Pickett EE. 1987. Atmopheric Pollution. Hemisphere Publ. Corp.
- Sharma SH and Khan TI. 2004. *Ozone Depletion and Environmental Impacts*. Pointer Publ.
- Weber E. 1982. *Air Pollution Assessment Methodology and Modeling*. Plenum Press.
- Yunus M and Iqbal M. (Eds.). 1996. *Plant Response to Air Pollution*. John Wiley & Sons.

Journal

- *Atmospheric Pollution* Research,
- *Environmental Pollution,*
- *Journal of Agrometeorology*

Website

- https://www.nationalgeographic.com/environment/global-warming/pollution/

I. **Course Title : Livestock and Fisheries Meteorology**

II. **Course Code : AGM 603**

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

IV. **Aim of the course**

To impart the theoretical and practical knowledge of weather, climate for livestockand fisheries management.

V. **Theory**

Unit I

Thermal balance in animals; energy exchange processes at the skin of the animals and the need for the maintenance of thermal balance in the animals. Animal traits and physiological responses.

Unit II

Effects of weather on animal production, loss of water from the body, growth rate and body weight, reproduction, grazing habit, food intake, milk production, sun burns and photosensitive disorders.

Unit III

Meteorological conditions prevailing in glass-house, green house, animal shed, poultry house and grain storage barns; heating, cooling and ventilation of these structures as governed by meteorological factors. Environmental modification within the shelters of livestock. Applications of biometeorological information for rational planning, design and management. Weather and animal diseases and parasites; diseases of poultry and its relation with weather and thermal comfort.

Unit IV

Livestock production and climate change, Management of livestock to reduce greenhouse gas emission.

Unit V

Weather effect on fish behaviour. Water temperature affecting fish activity. Marineweather and fishing. Climate change and fisheries production.

VI. **Practical**

- Measurement of meteorological parameters within the shelters of livestock
- Calculation of animal comfort zone index
- Radiation of animal farm house and body
- Estimation of enegy fluxes on body
- Measurements of CO_2 and methane in animal farm house.

VII. **Teaching methods/activities**

Class room teaching for theory part, visit to farm house for practical

VIII. **Learning outcome**

Enhanced knowledge on weather influence on livestock and farm environment

IX. **Suggested Reading**

- GSLHV Prasada Rao, GG Varma and Beena (Eds). 2017. *Livestock meteorology*. New India Publishing Agency- Nipa. 542 pages
- Kaiser HM and Drennen TE. (Eds). 1993. *Agricultural Dimensions of Global Climate Change*. St. Lucie Press, Florida.
- Monteith L and Unsworth M. 2007. *Principles of Environmental Physics*. 2nd Ed. Academic Press.
- Takahashi J, Young BA, Soliva CR and Kreuzer M. 2002. *Greenhouse Gases and Animal Agriculture*. Proc. 1st International Conference on Greenhouse Gases and Animal Agriculture.
- Tromp SW. 1980. *Biometeorology. The Impact of the Weather and Climate on Humans &their Environment*. (Animals and Plants). Heyden & Son Ltd.

Journals

- *Agricultural and Forest Meteorology,*
- *Journal* of *Animal Behaviour and Biometeorology,*
- *Journal of Agrometeorology*

Website

- www.wmo.org

I. **Course Title : Hydrometeorology**

II. **Course Code : AGM 604**

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

IV. **Aim of the course**

To impart the theoretical and practical knowledge of different components of hydrologic cycle.

V. **Theory**

Unit I

Hydrologic cycle and its modification; rainfall and its interception by plants and crops. Interpolation and measurement of missing rainfall data; adequacy of rain gauges; average rainfall on an area depth basis; presentation and processing of precipitation data.

Unit II

Measurement of runoff, infiltration, moisture retention of soil, percolation, evaporation, evapotranspiration and its importance to agriculturists, irrigation engineers and flood forecasting personnel; water holding capacity of soils, plant available water, cultural practices on soil moisture in relation to different phases of crop growth; evaporation from snow, lakes, reservoirs and crop fields.

Unit III

Classifying rainfall data into class interval; ranking of rainfall data; relationship between intensity and duration; methods of predicting runoff rate; factors affecting runoff; rainfall-runoff relation; estimation of evapotranspiration from water balance methods; response of crops to water stresses under different agroclimatic situation on India.

Unit IV

Moisture availability indices and their application for Indian condition; wet and dry spell by Markov-chain model; drought and its classification, hydrological drought, drought indices and their applications under Indian conditions.

VI. **Practical**

- Analysis of rainfall data
- Determination of effective rainfall
- To estimate missing rainfall data for a given station.
- To find out the optimum number of rain gauges for a given catchment.
- To find out the mean rainfall for a given drainage basin by Thiessen polygon method and isohyetal method.
- To estimate the volume of runoff by SCS method.
- Estimation of evopotranspiration from field based water balance method.

VII. **Teaching methods/activities**

Theory and practical classes

VIII. Learning outcome

Knowledge on rainfall analysis, runoff estimation, calculation of evaporation andthe relationship among different hydrological parameters

IX. Suggested Reading

- Chow, Ven Te (Ed.). 1964. *Handbook of Applied Hydrology.* McGraw-Hill.
- Hillel D. 1971. *Soil and Water.* Academic Press.
- Hillel D. 1980. *Application of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physics*. Academic Press.

Journal

- *Journal* of *Hydrology, Journal* of *Hydrology and Meteorology,*
- *Agricultural Water Management,*
- *Journal of Agrometeorology*

Website

- https://has.arizona.edu/meteorology-hydrology-and-hydrometeorology
- www.abb.com/cawp/seitp161/4f39ac092c0598c9c1256fb8004f7726.aspx

I. Course Title : Analytical Tools and Methods for Agro-meteorology
II. Course Code : AGM 605
III. Credit Hours : 1+1
IV. Aim of the course

To impart the theoretical and practical knowledge of new tools for analysis of agro-climatic features.

V. Theory

Unit I

Review of agro-climatic methods; characterization of agroclimatic elements; sampling of atmosphere; temporal and spatial considerations; micro-meso- macro climates.

Unit II

Network spacing; spatial and temporal methods; GIS fundamentals and applications; numerical characterization of climatic features; crop response to climate, time lags, time and distance constants, hysteresis effects.

Unit III

Influence of climate on stress-response relations; thermal time approach in agroclimatology- heat and radiation use efficiency in crop plants; applications to insect-pest development and prediction; comfort indices for human and animals;

impact of natural and induced variability and change of climate on crop production.

Unit IV

Instrumentation and sampling problems; design of agro-meteorological experiments.

Unit V

Basic knowledge of application of computers in agriculture; theories of computer language BASIC, FORTRAN, C, C++ and Visual basic.

Unit VI

Empirical and statistical crop weather models and their application with examples; incorporating weather, soil, plants and other environment related parameters as subroutine and remote sensing inputs in models; growth and yield prediction models; crop simulation models; forecasting models for insects and diseases.

VI. Practical

- Calculation of continentality factors.
- Climatic indices and climogram.
- Agrometeorological indices: Degree-days, photothermal units, heliothermal units,phenothermal index.
- Heat and radiation use efficiency and other indices of crops.
- Crop growth rates.
- Analysis of thermogram, hygrogram, hyetogram, sunshine cards etc. stream linesand wind roses and statistical analysis of climatic data.
- Working with statistical models: crop yield forecasting, crop weather relationshipand insect & disease forecasting models.
- Working with crop simulation models
- Small programme writing in computer languages like BASIC, FORTRAN, C, C++and Visual basic.
- Geographical Information System.

VII. Teaching methods/activities

Theory and practical classes, learning of computer language

VIII. Learning outcome

Knowledge on collection of agromet data, sampling design for agrometeorology,calculation of different indices and analysis of data

IX. Suggested Reading

- Cooper M. 2006. *The Spirit of C. An Introduction to Modern Programming*. Jaico Publ.
- Malczewski J. 1999. *GIS & Multicriteria Decision Analysis*. John Wiley & Sons.
- WMO. 2010. *Guide to agricultural meteorological practices*. Chapter 3: agriculturalmeteorological data, their presentation and statistical analysis

Journals

- *The International Journal* of *Database Management* Systems
- Journal of Agrometeorology
- https://www.tropmet.res.in/~icrp/icrpv12/adach.html
- www.wmo.int/pages/prog/wcp/agm/gamp/documents/WMO_No134_en.pdf

I. Course Title : Research and Publication Ethics
II. Course Code : AGM 606
III. Credit Hours : 2+0
IV. Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit IV

Publication ethics: Defination, introduction and importance. Best practices/ standard setting initiatives and guidelines: COPE, WAME etc., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatory publishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to check publisher copy right and self archiving policies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools, viz., JANE, Elsevier Journal Finder, Springer Journal Suggester etc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkundand other open source software tools.

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, etc. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, Gindex, i 10 index altmetrics

V. **Teaching methods/activities**

Classroom teaching and field and laboratory activities

VI. **Learning outcome**

To familiarize the students about field and laboratory activities to be performedduring the study period

I. **Course Title : Weather and Climate Risk Management**
II. **Course Code : AGM 607**
III. **Credit Hours : 3+0**
IV. **Aim of the course**

To impart the theoretical knowledge of Physics applied to atmosphere and meteorology

V. **Theory**

Unit I

Thermodynamics of the atmosphere. Physics of radiation: origin and nature of radiation, radiation geometry in Cartesian, spherical cylindrical coordinate systems,conservation principles for radiant energy; fluid motion: laminar and turbulent transfer, fluctuation theory for turbulent transfer of momentum, heat and water vapour.

Unit II

Physics of evaporation: aerodynamic approach, energy balance approach and combination approach for evaporation estimates.

Unit III

Physics of soil water system: the concept of potential as applied to soil water system, total potential and components, movements of water on soil, fundamental equation, hydraulic conductivity, infiltration, field drainage and water vapour movement in soil.

Unit IV

Physics of water use: a physical introduction to plant-water system and relationships, water transport through soil-plant-atmosphere systems, measurement of crop water use in terms of water conservation equation.

VI. Teaching methods/activities

Classroom teaching

VII. Learning outcome

Knowledge and application of physical laws governing the agrometeorological parameters

VIII. Suggested Reading

- Hillel D. 1971. *Soil and Water.* Academic Press.
- Hillel D. 1980. *Application of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physics*. Academic Press.
- Monteith JL .1973. *Principles of Environmental Physics.* Edward Arnold.
- Rose CW. 1966. *Agricultural Physics.* Pergamon Press.
- Sellers WD. 1965. *Physical Climatology*. University of Chicago Press.
- Van Wizk WR. 1963. *Physics of Plant Environment.* North-Holland Publishing.
- Waggoner PE. (Ed.). 1965. *Agricultural Meteorology*. American Meteorological Society.

Journals

- *Journal of Meteorological Research,*
- *Agricultural and Forest Meteorology*
- https://fmph.uniba.sk/.../enviromentalna-fyzika-obnovitelne-zdroje-energie-meteorolo...

I.	**Course Title**	**:**	**Computer Programs and Software for Agrometeorological Data Management**
II.	**Course Code**	**:**	**AGM 608**
III.	**Credit Hours**	**:**	**1+1**

IV. **Aim of the course**

To impart knowledge on management of agromet data and train the students in commercialization of agrometeorological data through e-services.

V. **Theory**

Unit I

Data and information; types of data; climate, soil and crop data; Importance of database management, Softwares related to database management; data requirements; data collection and recording (Automatic and manual).

Unit II

Data structure/format; quality control of data through computer software; techniques of climatic data generation; missing data; introduction to different software for database management.

Unit III

Processing and analysis of data and data products; value addition of data and data products; data users, public, commercial, academic or research. Availability, accessibility and security of data; evaluating the cost of data; e-management of data. Meta analysis: Advantages and problems, Steps, Approaches and methods, Applications.

Unit IV

Computer Programming: History, Quality requirements, Readability of source code,Algorithmic complexity, Debugging, Programming languages

VI. **Practical**

- Types of instruments and data recording
- AWS data retrieval, storage and transfer
- Exposure to different software for Agromet data analysis; exposure to Statisticalsoftware
- Temporal and spatial analysis of data; exposure to GIS
- Value addition to data
- Introduction to internet protocols
- Uploading and downloading data, password and security of data
- E-management of data
- Introduction to computer programming

VII. **Teaching methods/activities**

Hands on practical and theory

VIII. **Learning outcome**

Learning computer programming to manage and analyze agromet data

- Ghadekar R. 2002. *Practical Meteorology – Data Acquisition Techniques, Instruments and Methods*. 4th Ed. Agromet Publ.
- IMD/ WHO. 1988. *Users Requirements for Agrometeorological Services.* IMD.
- Miles MB and Huberman AM. 1994. *Qualitative Data Analysis*. Sage Publ.
- Panse VG and Sukhatme PV. 1983. *Statistical Methods for Agricultural Workers,* ICAR.
- Potter GB. 1994. *Data Processing: An Introduction*. Business Publ.
- Ramakrishnan R and Gehrke J. 2003. *Database Management System*. McGraw-Hill.
- Sinha PK and Sinha P. 2004. *Computer Fundamentals*. BPB Publications. (6th Edn).

Journals

- *The Journal* of *Database Management*
- *International Journal* of Data Mining
- *Modelling and Management*

Websites

- https://www.cics.umass.edu/research/area/data-management
- https://www.referenceforbusiness.com/management/.../Data-Processing-and-Data-Man.

GENETICS AND PLANT BREEDING

Course Title with Credit Load for M.Sc. Genetics and Plant Breeding

Course Code	Course Title	Credit Hours
GPB 501*	Principles of Genetics	3 (2+1)
GPB 502*	Principles of Plant Breeding	3 (2+1)
GPB 503*	Fundamentals of Quantitative Genetics	3 (2+1)
GPB 504	Varietal Development and Maintenance Breeding	2 (1+1)
GPB 505	Principles of Cytogenetics	3 (2+1)
GPB 506*	Molecular Breeding and Bioinformatics	3 (2+1)
GPB 507	Breeding for Quality and Special Traits	3 (2+1)
GPB 508	Mutagenesis and Mutation Breeding	3 (2+1)
GPB 509	Hybrid Breeding	3 (2+1)
GPB 510	Seed Production and Certification	2 (1+1)
GPB 511	Crop Breeding-I *(Kharif* Crops)	3 (2+1)
GPB 512	Crop Breeding-II *(Rabi* Crops)	3 (2+1)
GPB 513	Breeding Vegetable Crops	3 (2+1)
GPB 514	Breeding Fruit Crops	3 (2+1)
GPB 515	Breeding Ornamental Crops	3 (2+1)
GPB 516	Breeding for Stress Resistance and Climate Change	3 (2+1)
GPB 517	Germplasm Characterization and Evaluation	2 (1+1)
GPB 518	Genetic enhancement for PGR Utilization	2 (1+1)
GPB 519	Breeding of Tropical Crops	2 (2+0)
GP 520	Genetics	2 (2+0)
GPB 591	Master’s Seminar	0+1
GPB 599	Master’s Research	30

*Compulsory Major Courses

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

II. **Course Code** : **GPB 501**

III. **Credit Hours** : **3 (2+1)**

IV. **Why this course?**

Genes are the backbone of all crop improvement activities. Their chemical structure and physical inheritance are pivotal for any breeding program. Therefore, it has tobe the core course for master's degree in Genetics and Plant Breeding.

V. **Aim of the course**

This course is aimed at understanding the basic concepts of inheritance of genetic traits, helping students to develop their analytical, quantitative and problem-solving skills from classical to molecular genetics.

VI. **Theory**

Unit I

Beginning of genetics**,** early concepts of inheritance, Mendel's laws; Discussion on Mendel's paper, Chromosomal theory of inheritance;Multiple alleles, Gene interactions, Sex determination, differentiation and sex-linkage, Sex-influenced and sex-limited traits; Linkage-detection, estimation; Recombination and genetic mapping in eukaryotes, Somatic cell genetics, Extra chromosomal inheritance.

Unit II

Mendelian population, Random mating population, Frequencies of genes and genotypes, Causes of change: Hardy-Weinberg equilibrium.

Unit III

Nature, structure and replication of the genetic material; Organization of DNA in chromosomes, Genetic code; Protein biosynthesis, Genetic fine structure analysis, Allelic complementation, Split genes, overlapping genes, Pseudogenes, Oncogenes, Gene families and clusters; Regulation of gene activity in prokaryotes and eukaryotes; Molecular mechanisms of mutation, repair and suppression; Bacterial plasmids, insertion (IS) and transposable (Tn) elements; Molecular chaperones and gene expression, RNA editing.

Unit IV

Gene isolation, synthesis and cloning, genomic and cDNA libraries, PCR based cloning, positional cloning; Nucleic acid hybridization and immunochemical detection; DNA sequencing; DNA restriction and modification, Anti-sense RNA and ribozymes;Micro-RNAs (miRNAs).

Unit V

Genomics and proteomics; metagenomics; Transgenic bacteria and bioethics; Gene silencing; genetics of mitochondria and chloroplasts. Concepts of Eugenics, Epigenetics, Genetic disorders.

VII. Practical

- Laboratory exercises in probability and chi-square;
- Demonstration of genetic principles using laboratory organisms;
- Chromosome mapping using three-point test cross;
- Tetrad analysis; Induction and detection of mutations through genetic tests;
- DNA extraction and PCR amplification;
- Electrophoresis: basic principles and running of amplified DNA;
- Extraction of proteins and isozymes;
- Use of *Agrobacterium* mediated method and Biolistic gun;
- Detection of transgenes in the exposed plant material;
- Visit to transgenic glasshouse and learning the practical considerations.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After passing out this course the student will be able to know the difference between the genotype and phenotype, can carry study on inheritance and also know the role of DNA and RNA in genotypic manifestation of characters.

X. Suggested reading

- Daniel LH and Maryellen R. 2011. *Genetics: –Analysis of Genes and Genomes‖*.
- Gardner EJ and Snustad DP. 1991. *Principles of Genetics*. John Wiley and Sons. 8th ed. 2006 Klug WS and Cummings MR. 2003. *Concepts of*

Genetics. Peterson Edu. Pearson Education India; Tenth edition

- Lewin B. 2008. *Genes XII*. Jones and Bartlett Publ. (International Edition) Paperback, 2018 Russell PJ. 1998. *Genetics*. The Benzamin/ Cummings Publ. Co
- Singh BD. 2009. *Genetics*. Kalyani Publishers (2nd Revised Edition)
- Snustad DP and Simmons MJ. 2006. *Genetics*. 4th Ed. John Wiley and Sons. 6th Edition International Student Version edition
- Stansfield WD.1991. *Genetics*.Schaum Outline Series Mc Graw Hill
- Strickberger MW. 2005. *Genetics* (*III Ed*). Prentice Hall, New Delhi, India; 3rd ed., 2015 Tamarin RH. 1999. *Principles of Genetics*. Wm. C. Brown Publs., McGraw Hill Education; 7 dition
- Uppal S, Yadav R, Singh S and Saharan RP. 2005. *Practical Manual on Basic and Applied Genetics*. Dept. of Genetics, CCS HAU Hisar.

I. Course Title : Principles of Plant Breeding*

II. Course Code : GPB 502

III. Credit Hours : 3(2+1)

IV. Why this course?

Development of plant variety is the ultimate aim of any plant breeding program. A post graduate in the subject of agriculture must know what are the different selection methods, techniques and related crop improvement strategies.Further, knowledge of genetic resources, evolution and their role in development of noble varieties is the need of the hour.

V. Aim of the course

To impart theoretical knowledge and practical skills about plant breeding objectives, genetic consequences, breeding methods for crop improvement.

VI. Theory

Unit I

Early Plant Breeding; Accomplishments through plant breeding; Objectives of plant breeding; Patterns of Evolution in Crop Plants: Centre of Origin, Agro-biodiversity and its significance. Pre-breeding and plant introduction and role of plant genetic resources in plant breeding.

Unit II

Genetic basis of breeding: self and cross pollinated crops including mating systems and response to selection; Nature of variability, components of variation; Heritability and genetic advance, genotype environment interaction;

General and specific combining ability; Types of gene actions and implications in plant breeding.

Unit III

Pure line theory, pure line and mass selection methods; pedigree, bulk, backcross, single seed descent and multiline breeding; Population breeding in self-pollinated crops with special reference to diallel selective mating; Transgressive breeding.

Unit IV

Breeding methods in cross pollinated crops; Population breeding: mass selection and ear-to-row methods; S_1 and S_2 progeny testing, progeny selection schemes, recurrent selection schemes for intra and inter-population improvement and development of synthetics and composites. Hybrid breeding: genetical and physiological basis of heterosis and inbreeding, production of inbreeds, breeding approaches for improvement of inbreeds, predicting hybrid performance; seed production of hybrid and their parent varieties/ inbreeds. Self-incompatibility, male sterility and apomixes in crop plants and their commercial exploitation.

Unit V

Breeding methods in asexually/ clonally propagated crops, clonal selection.

Unit VI

Special breeding techniques: Mutation breeding, Breeding for abiotic and biotic stresses; Concept of plant ideotype and its role in crop improvement, conceptof MAS, concept of polyploidy and wide hybridization, doubled haploidy.

Unit VII

Cultivar development: testing, release and notification, maintenance breeding, Participatory Plant Breeding, Plant breeders' rights and regulations for plant varietyprotection and farmers rights.

VII. Practical

- Floral biology in self and cross pollinated species;
- Selfing and crossing techniques;
- Selection methods in segregating populations and evaluation of breeding material;
- Analysis of variance (ANOVA);
- Estimation of heritability and genetic advance;
- Maintenance of experimental records;
- Learning techniques in hybrid seed production using male-sterility in field crops;

- Prediction of performance of double cross hybrid.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

The knowledge of this course will enable the student to know breeding methods, different hybridization techniques for genomic reshuffling. The course will also acquaint the student with importance of floral biology, mutation breeding andparticipatory plant breeding, etc.

X. Suggested Reading

- Allard RW. 1981. *Principles of Plant Breeding*. John Wiley & Sons.
- Chahal GS and Gossal, SS. 2002. *Principles and Procedures of Plant Breeding Biotechnological and Conventional approaches.* Narosa Publishing House.
- Chopra VL. 2004. *Plant Breeding*. Oxford & IBH.
- George A. 2012. *Principles of Plant Genetics and Breeding*. John Wiley & Sons. Gupta SK. 2005. *Practical Plant Breeding*. Agribios.
- Jain HK and Kharakwal MC. 2004. *Plant Breeding and–Mendelian to Molecular Approach,* Narosa Publications, New Delhi
- Roy D. 2003. *Plant Breeding, Analysis and Exploitation of Variation*. Narosa Publ. House. Sharma JR. 2001. *Principles and Practice of Plant Breeding*. Tata McGraw-Hill.
- Sharma JP. 2010. Principles of Vegetable Breeding. Kalyani Publ, New Delhi. Simmonds NW.1990. *Principles of Crop Improvement*. English Language Book Society. Singh BD. 2006. *Plant Breeding*. Kalyani Publishers, New Delhi.
- Singh S and Pawar IS. 2006. *Genetic Bases and Methods of Plant Breeding*. CBS.

I. **Course Title** : **Fundamentals of Quantitative Genetics***

II. **Course Code** : **GPB 503**

III. **Credit Hours** : **3 (2+1)**

IV. **Why this course?**

Yield and quality characters are controlled by many genes and show the quantitative inheritance. If one has to go for improvement even for the components characters the knowledge of this course is very essential.

V. **Aim of the course**

To impart theoretical knowledge and computation skills regarding components of variation and variances, scales, mating designs and gene effects.

VI. **Theory**

Unit I

Introduction and historical background of quantitative genetics, Multiple factor hypothesis, Qualitative and quantitative characters, Analysis of continuous variation mean, range, SD, CV; Components of variation- Phenotypic,Genotypic, Nature of gene action- additive, dominance and epistatic, linkage effect. Principles of analysis

of variance and linear model, Expected variance components, Random and fixed effect model, Comparison of means and variances for significance.

Unit II

Designs for plant breeding experiments- principles and applications; Variability parameters, concept of selection, simultaneous selection modes and selection of parents, MANOVA.

Unit III

Association analysis- Genotypic and phenotypic correlation, Path analysis Discriminate function and principal component analysis, Genetic divergence analysis- Metroglyph and D^2, Generation mean analysis, Parent progeny regression analysis

Unit IV

Mating designs- classification, Diallel, partial diallel, L × T, NCDs, and TTC; Concept of combining ability and gene action, G × E interaction- Adaptability and stability; Methods and models for stability analysis; Basic models- principles and interpretation, Bi-plot analysis.

Unit V

QTL mapping, Strategies for QTL mapping- Desired population and statistical methods, QTL mapping in genetic analysis; Markers, Marker assisted selection and factors influencing the MAS, Simultaneous selection based on marker andphenotype.

VII. Practical

- Analysis and interpretation of variability parameters;
- Analysis and interpretation of Index score and Metroglyph;
- Clustering and interpretation of D^2 analysis;
- Genotypic and phenotypic correlation analysis and interpretation;
- Path coefficient analysis and interpretation, Estimation of different types ofheterosis, inbreeding depression and interpretation;
- A, B and C Scaling test;
- L × T analysis and interpretation, QTL analysis;
- Use of computer packages;
- Diallel analysis;
- G × E interaction and stability analysis.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures,
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After studying this course, the student will be equipped with the knowledgeof additive dominance and epistatic gene action. He will also be introduced withthe various designs for analysis of genotypic and phenotypic variance and QTL mapping.

X. Suggested Reading

- Bos I and Caligari P. 1995. *Selection Methods in Plant Breeding*. Chapman & Hall.
- Falconer DS and Mackay J. 1998. *Introduction to Quantitative Genetics* (3rd Ed.).ELBS/ Longman, London.
- Mather K and Jinks JL.1985. *Biometrical Genetics* (3rd Ed.). Chapman and Hall, London.
- Nandarajan N and Gunasekaran M. 2008. *Quantitative Genetics and*

Biometrical Techniques in Plant Breeding. Kalyani Publishers, New Delhi.

- Naryanan SS and Singh P. 2007. *Biometrical Techniques in Plant Breeding*. Kalyani Publishers, New Delhi.
- Roy D. 2000. *Plant Breeding: Analysis and Exploitation of Variation*. Narosa Publishing House, New Delhi.
- Sharma JR. 2006. *Statistical and Biometrical Techniques in Plant Breeding*. New Age International Pvt. Ltd.
- Singh P and Narayanan SS. 1993. *Biometrical Techniques in Plant Breeding.* Kalyani Publishers, New Delhi.
- Singh RK and Chaudhary BD. 1987. *Biometrical Methods in Quantitative Genetic* analysis. Kalyani Publishers, New Delhi.
- Weir DS. 1990. *Genetic Data Analysis. Methods for Discrete Population Genetic Data*. Sinauer Associates.
- Wricke G and Weber WE. 1986. *Quantitative Genetics and Selection in Plant Breeding*. Walter de Gruyter.

e-Suggested Reading

www.iasri.icar.gov.in www.hau.ac.in/OPstat

I. **Course Title : Varietal Development and Maintenance Breeding**

II. **Course Code : GPB 504**

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

IV. **Why this course?**

It is an indispensable course which apprise the students about various practices and procedures in the development of a variety and steps to maintain the purity of varieties/ hybrids. Further, it provides basics of nucleus and breeder seed production techniques.

V. **Aim of the course**

The purpose of this course is to make students well acquainted with the techniques and procedures of varietal development. He will be associated with development of variety so the course aims is to provide knowledge on DUS testing, protocols of various breeding techniques, procedures of release of variety, maintenance of the variety and production of nucleus and breeder seed of variety/ hybrids.

VI. **Theory**

Unit I

Variety Development systemsand Maintenance; Definition- variety, cultivar, extant variety, essentially derived variety, independently derived variety, reference variety, farmers' variety, landraces, hybrid, and population; Variety testing, release and notification systems and norms in India and abroad.

Unit II

DUS testing- DUS Descriptors for major crops; Genetic purity concept and maintenance breeding. Factors responsible for genetic deterioration of varieties - safeguards during seed production.

Unit III

Maintenance of varieties in self and cross pollinated crops, isolation distance; Principles of seed production; Methods of nucleus and breeder seed production; Generation system of seed multiplication -nucleus, breeders, foundation, certified.

Unit IV

Quality seed production technology of self and cross-pollinated crop varieties, viz., cereals and millets (wheat, barley, paddy, pearlmillet, sorghum, maize and ragi, etc.); Pulses (greengram, blackgram, cowpea, pigeonpea, chickpea, fieldpea, lentil); Oilseeds (groundnut, soybean, sesame, castor, sunflower, safflower, linseed, rapeseed and mustard); fibres (cotton/ jute) and forages (guar, forage sorghum, teosinte, oats, berseem, lucerne).

Unit V

Seed certification procedures; Seed laws and acts, plant variety protection regulationsin India and international systems.

VII. Practical

- Identification of suitable areas/ locations for seed production;
- Ear-to-row method and nucleus seed production;
- Main characteristics of released and notified varieties, hybrids and parental lines;
- PGMS and TGMS;
- Identification of important weeds/ objectionable weeds;
- Determination of isolation distance and planting ratios in different crops; Seedproduction techniques of varieties in different crops;
- Hybrid seed production technology of important crops;
- DUS testing and descriptors in major crops;
- Variety release proposal formats in different crops.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

Pass out student will have complete knowledge on the various procedures linked with the development and release of variety. This course will also enable student how to maintain and multiply variety for large scale distribution. It will also make student acquainted with the seed laws and acts related to plant variety protection.

X. Suggested Reading

- Agarwal RL. 1997. *Seed Technology*. 2nd Ed. Oxford & IBH. Kelly AF. 1988. *Seed Production of Agricultural Crops*. Longman.
- McDonald MB Jr and Copeland LO. 1997. *Seed Production: Principles and Practices*. Chapman & Hall.
- Poehlman JM and Borthakur D. 1969. *Breeding Asian Field Crops*. Oxford & IBH. Singh BD. 2005. *Plant Breeding: Principles and Methods*. Kalyani. 2015 Thompson JR. 1979. *An Introduction to Seed Technology*. Leonard Hill

I. Course Title : Principles of Cytogenetics
II. Course Code : GPB 505
III. Credit Hours : 3 (2+1)

IV. Why this course?

The very purpose of this course is to acquaint the students with cell cycle and architecture of chromosome in prokaryotes and eukaryotes, special types of chromosomes, techniques for karyotyping. This course aims to impart knowledgeof variations in chromosomes numbers and their structures. It acquaints the students for the production and use of haploids, apomictic populations and their role in genetics and breeding.

V. Aim of the course

To provide insight into structure and functions of chromosomes, chromosome mapping, polyploidy and cytogenetic aspects of crop evolution.

VI. Theory

Unit I

Cell cycle and architecture of chromosome in prokaryotes and eukaryotes; cell organelles- ultra structure and functions Chromonemata, chromosome matrix, chromomeres, centromere, secondary constriction and telomere ; Special types of chromosomes. Variation in chromosome structure: Evolutionary significance; Introduction to techniques for karyotyping; Chromosome banding and painting -*In situ* hybridization and various applications.

Unit II

Structural and numerical variations of chromosomes and their implications; Symbols and terminologies for chromosome numbers, euploidy, haploids, diploids and polyploids; Utilization of aneuploids in gene location; Variation in chromosome behaviour, somatic segregation and chimeras, endomitosis and somatic reduction; Evolutionary significance of chromosomal aberrations, balanced lethal and chromosome complexes; Inter-varietal chromosome substitutions.

Unit III

Fertilization barriers in crop plants at pre-and postfertilization levels; *In-vitro* techniques to overcome the fertilization barriers in crops; Polyploidy. Genetic consequences of polyploidization and role of polyploids in crop breeding; Evolutionary advantages of autopolyploid *vs* allopolyploids; Role of aneuploids in basic and applied aspects of crop breeding, their maintenance and utilization in gene mapping and gene blocks transfer; Alien addition and substitution lines, creation and utilization; Apomixis, evolutionary and genetic problems in crops with apomixes.

Unit IV

Reversion of autopolyploid to diploids; Genome mapping in polyploids; Interspecific hybridization and allopolyploids; Synthesis of new crops (wheat, *Triticale*, *Brassica***,** and cotton); Hybrids between species with same chromosome number, alien translocations; Hybrids between species with different chromosome number; Gene transfer using amphidiploids, bridge species.

Unit V

Chromosome manipulations in wide hybridization; case studies; Production and use of haploids, dihaploids and doubled haploids in genetics and breeding.

VII. Practical

- Learning the cytogenetical laboratory techniques, various chemicals to be usedfor fixation, dehydration, embedding, staining, cleaning, etc.;
- Microscopy: various types of microscopes;
- Preparing specimen for observation;
- Fixative preparation and fixing specimen for light microscopy studies in cereals;
- Studies on mitosis and meiosis in crop plants;
- Using micrometres and studying the pollen grain size in various crops. Pollengermination *in vivo* and *in-vitro*;
- Demonstration of polyploidy.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

The course will provide full knowledge to the student on the various procedures linked with cell development and chromosome structure and function. Thiscourse will also enable student how to tailor and utilize the variation in chromosome number and structures in the development and synthesis of new species and varieties.

X. Suggested Reading

- Becker K and Hardin J. 2004. *World of the Cell*. 5th Ed. Pearson Edu. 9th edition. Carroll M. 1989. *Organelles*. The Guilford Press.
- Charles B. 1993. *Discussions in Cytogenetics*. Prentice Hall Publications.
- Darlington CD and La Cour LF. 1969. *The Handling of Chromosomes*. George Allen & Unwin Ltd.
- Elgin SCR. 1995. *Chromatin Structure and Gene Expression*. IRLPress,Oxford.
- Gupta PK and Tsuchiya T. 1991. *Chromosome Engineering in Plants: Genetics, Breeding and Evolution*. Part A.

- Gupta PK. 2010. *Cytogenetics*. Rastogi Pubishers. Johannson DA. 1975. *Plant Micro technique*. McGraw Hill.
- Karp G. 1996. *Cell and Molecular Biology: Concepts and Experiments*. John Wiley & Sons. Khush GS. 1973. *Cytogenetics of aneuploids*. Elsevier. 1 edition.
- Roy D.2009. *Cytogenetics*. Alpha Science Intl Ltd.
- Schulz SJ.1980. *Cytogenetics- Plant, animals and Humans*. Springer.
- Sharma AK and Sharma A. 1988. *Chromosome Techniques: Theory and Practice*. Butterworth- Heinemann publisher 2014.3rd edition
- Singh RJ. 2016. Plant *Cytogenetics* 3rd Edition. CRC Press.
- Sumner AT. 1982. *Chromosome Banding*. Unwin Hyman Publ. 1 edition, Springer pub. Swanson CP. 1960. *Cytology and Cytogenetics*. Macmillan & Co.

I. Course Title : Molecular Breeding and Bioinformatics*

II. Course Code : GPB 506

III. Credit Hours : 3(2+1)

IV. Why this course?

The course will provide deep knowledge to the students on genotyping and kinds of markers including biochemical and molecular, mapping populations, allele mining. This will also add ways to perform marker- assisted selection and gene pyramidingto evolve superior varieties.

V. Aim of the course

To impart knowledge and practical skills to use innovative approaches and Bioinformatics in Plant Breeding.

VI. Theory

Unit I

Genotyping; Biochemical and Molecular markers; Morphological, biochemical and DNA-based markers (RFLP, RAPD, AFLP, SSR, SNPs, ESTs, etc.), Functional markers; Mapping populations (F_2s, back crosses, RILs, NILs and DH); Molecular mapping and tagging of agronomically important traits; Statistical tools in marker analysis.

Unit II

Allele mining; Marker-assisted selection for qualitative and quantitative traits; QTLs analysis in crop plants; Marker-assisted backcross breeding for rapid introgression; Genomics- assisted breeding; Generation of EDVs;

Gene pyramiding.

Unit III

Introduction to Comparative Genomics; Large scale genome sequencing strategies; Human genome project; Arabidopsis genome project; Rice genome project; Comparative genomics tools; Introduction to proteomics; 2D gel electrophoresis; chromatography and sequencing by Edman degradation and mass spectrometry; Endopeptidases; Nanotechnology and its applications in crop improvement.

Unit IV

Recombinant DNA technology, transgenes, method of transformation, selectable markers and clean transformation techniques, vector-mediatedgene transfer, physical methods of gene transfer; Production of transgenic plants in various field crops: cotton, wheat, maize, rice, soybean, oilseeds, sugarcane, etc. and commercial releases; Biotechnology applications in male sterility/ hybrid breeding, molecular farming; Stress resistance breeding,introductory basics of gene editing technologies like CRISPR-CAS, ZFN, TALENS etc. and gene silencing technologies like antisense RNA technology, microRNA ; Application of Tissue culture in molecular breeding; MOs and related issues (risk and regulations); GMO; International regulations, biosafety issues of GMOs; Regulatory procedures in major countries including India, ethical, legal and social issues; Intellectual property rights

Unit V

Introduction to bioinformatics: bioinformatics tools, biological data bases (primary and secondary), biological data storage sites, data searching and retrieving, synteny and its applications, identification of desired gene sequences, implications in crop improvement.

VII. Practical

- Requirements for plant tissue culture laboratory;
- Techniques in plant tissue culture;
- Media components and media preparation;
- Aseptic manipulation of various explants, observations on the contaminantsoccurring in media, interpretations;
- Inoculation of explants, callus induction and plant regeneration; Standardizingthe protocols for regeneration;
- Hardening of regenerated plants; Establishing a greenhouse and hardeningprocedures;
- Visit to commercial micropropagation unit;

- Transformation using Agrobacterium strains;
- GUS assay in transformed cells/ tissues;
- DNA isolation, DNA purity and quantification tests;
- Gel electrophoresis of proteins and isozymes, PCR-based DNA markers, gel scoring and data analysis for tagging and phylogenetic relationship;
- Construction of genetic linkage maps using computer software;
- NCBI Genomic Resources, GBFF, Swiss Prot, Blast n/ Blast p, Gene PredictionTool, Expasy Resources, PUBMED and PMC, OMIM and OMIA, ORF finder;
- Comparative Genomic Resources: - Map Viewer (UCSC Browser and Ensembl);
- Primer designing- Primer 3/ Primer BLAST.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning Outcome

The knowledge of this course will enable the student to know about various molecular tools and approaches for genotyping and marker assisted breeding, intellectual property rights, bioinformatics tools and their uses in crop improvement.

X. Suggested Reading

- Azuaje F and Dopazo J. 2005. *Data Analysis and Visualization in Genomics and Proteomics.* John Wiley and Sons.
- Brown TA. 1991. *Essential Molecular Biology: a practical Approach*. Oxford university press, 2002, 2nd edition
- Chawala HS. 2000. *Introduction to Plant Biotechnology*. Oxford & IBH Publishing Co. Pvt. Ltd.
- Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology: Concepts, Methods and Applications*. Oxford & IBH.
- Gupta PK. 1997. *Elements of Biotechnology*. Rastogi Publ.

- Hackett PB, Fuchs JA and Messing JW. 1988. *An Introduction to Recombinant DNA Technology Basic Experiments in Gene Manipulation*. 2nd Ed. Benjamin Publ. Co.

- Jollès P and Jörnvall H. 2000. *Proteomics in Functional Genomics: Protein Structure Analysis*. Birkhäuser.
- Lewin B. 2017. *Genes XII*. Jones & Bartlett learning, 2017.
- Robert NT and Dennis JG. 2010. *Plant Tissue Culture, Development,and Biotechnology.* CRC Press.
- Sambrook J and Russel D. 2001. *Molecular Cloning - a Laboratory Manual*. 3rd Ed. Cold SpringHarbor Lab. Press.
- Singh BD. 2005. *Biotechnology, Expanding Horizons*. Kalyani Publishers, New Delhi. Watson J. 2006. *Recombinant DNA*. Cold Spring harbor laboratory press.

I. Course Title : Breeding for Quality and Special Traits

II. Course Code : GPB 507

III. Credit Hours : 3(2+1)

IV. Why this course?

Quality consciousness is growing in the society and only quality productsare in

demand in the market so has to be the new varieties. This course acquaints breeding for grain quality parameters in field crops. It will also teach about the genetic engineering protocols for quality improvement: Biofortification in crops andNutritional genomics and Second generation transgenics.

V. Aim of the course

To provide insight into recent advances in improvement of quality traits in cereals, millets, legumes, oilseeds, forage and industrial crops using conventional and modern biotechnological approaches.

VI. Theory

Unit I

Developmental biochemistry and genetics of carbohydrates, proteins, fats, vitamins, amino acids and anti-nutritional factors; Nutritional improvement - A human perspective.

Unit II

Breeding for grain quality parameters in rice and its analysis; Golden rice andaromatic rice: Breeding strategies, achievements and application in Indian context; Molecular basis of quality traits and their manipulation in rice; Post harvest manipulation for quality improvement; Breeding for baking qualities in wheat, characters to be considered and breeding strategies, molecular and cytogeneticmanipulation for quality improvement in wheat.

Unit III

Breeding for quality improvement in Sorghum, pearl millet, barley and oats; Quality protein maize, specialty corns, concept and breeding strategies; Breeding for quality improvement in important forage crops for stay green traits; Genetic resource management for sustaining nutritive quality in crops.

Unit IV

Breeding for quality improvement in pulses – Chickpea, pigeonpea, green gramand black gram cooking quality; Breeding for quality in oilseeds -groundnut**,** mustard, soybean, sesame, sunflower and minor oilseeds; Molecular basis of fat formation and manipulation to achieve more PUFA in oil crops; Genetic manipulation for quality improvement in cotton. Breeding for quality improvement in Sugarcane, potato.

Unit V

Genetic engineering protocols for quality improvement: Achievements made; Biofortification in crops; Classification and importance, Nutritional genomics and Second generation transgenics.

VII. Practical

- Grain quality evaluation in rice; Correlating ageing and quality improvement inrice;
- Quality analysis in millets;
- Estimation of anti-nutritional factors like tannins in different varieties/ hybrids:A comparison;
- Quality parameters evaluation in wheat, pulses and oilseeds;
- Evaluation of quality parameters in cotton, sugarcane and potato;
- Value addition in crop plants;
- Post-harvest processing of major field crops;
- Quality improvement in crops through tissue culture techniques;
- Evaluating the available populations like RIL, NIL, etc. for quality improvementusing MAS procedures;
- Successful example of application of MAS for quality trait in rice, mustard, maize,etc.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

The knowledge of this course will expose the student to know about various conventional and genetic engineering techniques for the improvement of quality characters in agricultural and horticultural field crops.

X. Suggested Reading

Chahal GS and SS Ghosal. 2002. *Principles and procedures of plant breeding - Biotechnological and Conventional approaches*, Narosa Publications ChopraVL. 1997. *Plant Breeding*. Oxford & IBH. 2018.

FAO 2001. *SpecialityRices of the World - Breeding, Production and Marketing*. Oxford & IBH,1 Nov 2001.

Ghosh P. 2004. *Fibre Science and Technology*. Tata McGraw Hill.

Gupta SK. 2007. *Advances in Botanical Research* Vol. 45 Academic PressUSA. Hay RK. 2006. *Physiology of Crop Yield*. 2nd Ed. Blackwell.

Nigam J. 1996. *Genetic Improvement of Oilseed Crops*. Oxford & IBH. Singh BD. 1997. *Plant Breeding*. Kalyani Publishers, New Delhi.

Singh RK, Singh UK and Khush GS. 2000. *Aromatic Rices*. Oxford & IBH.

I. Course Title : Mutagenesis and Mutation Breeding

II. Course Code : GPB 508

III. Credit Hours : 3 (2+1)

IV. Why this course?

The knowledge of this course will enable the students to learn about mutation, various methods of inducing mutations and their utilization in plant breeding. It will also give in depth knowledge about genomics, allele mining, TILLING, etc. andtheir utilization in crop improvement programmes.

V. Aim of the course

To impart the knowledge about general principles of mutagenesis for crop improvement and various tests/ methods for detection of mutations.

VI. **Theory**

Unit I

Mutation and its history, nature and classification of mutations: spontaneous and induced mutations, micro and macro mutations, pre and post adaptive mutations; Detection of mutations. Paramutations in crops plants.

Mutagenic agents: physical – radiation types and sources: Ionizing and non-ionizingradiations. Radiobiology: mechanism of action of various radiations (photoelectric absorption, Compton scattering and pair production) and their biological effects – RBE and LET relationships; Effect of mutations on DNA – repair mechanisms operating at DNA, chromosome, cell and organism level to counteract the mutation effects; Dosimetry -Objects and methods of treatment; Factors influencing mutation: dose rate, acute vs chronic irradiation, recurrent irradiation, enhancement of thermal neutron effects; Radiation sensitivity and modifying factors: External and internal sources – Oxygen, water content, temperature and nuclear volume.

Unit III

Chemical mutagens: Classification – base analogues, antibiotics, alkylating agents, acridine dyes and other mutagens: their properties and mode ofaction; Dose determination and factors influencing chemical mutagenesis; Treatment methods using physical and chemical mutagens, Combination treatments; other causes of mutation – direct and indirect action, comparative evaluation of physical and chemical mutagens.

Unit IV

Observing mutagen effects in M_1 generation: plant injury, lethality, sterility, chimeras, etc.; Observing mutagen effects in M_2 generation; Estimation of mutagenicefficiency and effectiveness – spectrum of chlorophyll and viable mutations; Mutations in traits with continuous variation; Factors influencing the mutant spectrum: genotype, type of mutagen and dose, pleiotropy and linkage, etc.; Individual plant based mutation analysis and working out effectiveness and efficiency in M_3 generation; Comparative evaluation of physical and chemical mutagens for creation of variability in the some species- Case studies.

Unit V

Use of mutagens in creating oligogenic and polygenic variations – Case studies; *In-vitro* mutagenesis – Callus and pollen irradiation; Handling of segregating M_2 generations and selection procedures; Validation of mutants; Mutation breeding for various traits (disease resistance, insect resistance, quality improvement, etc.) in different crops; Procedures for micromutations breeding/ polygenic mutations; Achievements of mutation breeding- varieties released across the world, problems associated with mutation breeding. Use of mutagens in genomics, allele mining, TILLING.

VII. Practical

- Precautions on handling of mutagens; Dosimetry-Studies of different mutagenic agents:Physical mutagens and Chemical mutagens;
- Learning on Radioactivity- Production source and isotopes at BRIT, Trombay, Learning about gamma chamber;
- Radiation hazards: Monitoring – safety regulations and safe transportation of radioisotopes, visit to radio isotope laboratory; learning on safe disposal of radioisotopes;
- Hazards due to chemical mutagens – Treating the plant propagules at different doses of physical and chemical mutagens;
- Procedures in combined mutagenic treatments;
- Raising the crop for observation; Mutagenic effectiveness and efficiency, calculating the same from earlier literature;
- Study of M_1 generation – Parameters;
- Study of M_2 generation – Parameters;
- Mutation breeding in cereals and pulses-achievements made and an analysis;
- Mutation breeding in oilseeds and cotton- achievements and opportunities;
- Mutation breeding in forage crops and vegetatively propagated crops;
- Procedure for detection of mutations for polygenic traits in M_2 and M_3 generations.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

This course will make the student well versed with the process of mutation and its use in crop improvement. This course will also give in depth knowledge of mutations in genomics, allele mining and TILLING.

X. **Suggested Reading**

- Alper T. 1979. *Cellular Radiobiology*. Cambridge Univ. Press, London.
- Chadwick KH and Leenhouts HP. 1981. *The Molecular Theory of Radiation Biology*. Springer- Verlag.
- Cotton R, Edkin E and Forrest S. 2000. *Mutation Detection: A Practical Approach*. Oxford Univ. Press.
- International Atomic Energy Agency. 1970. *Manual on Mutation Breeding*. International Atomic Energey Agency, Vienna, Italy.
- Shu QY, Forster BP and Nakagawa N. 2012. *Plant Mutation Breeding and Biotechnology*.
- Gutecnberg Press Ltd. Rome Italy ISBN:978-925107-022-2 (FAO).
- Singh BD. 2003. *Genetics*. Kalyani Publishers, New Delhi. Strickberger MW. 2005. *Genetics*. 3rd Ed. Prentice Hall. www.barc.gov.in

I. **Course Title : Hybrid Breeding**

II. **Course Code : GPB 509**

III. **Credit Hours : 3(2+1)**

IV. **Why this course?**

This course will expose the students with the basic concepts of hybrid varietiesand various techniques for development of hybrids in crop plants. This will also give an overview of various kinds of male sterility and their utilization in hybrid seed production of important field crops.

V. **Aim of the course**

To provide knowledge of understanding about mechanisms of heterosis and its exploitation for yield improvement through conventional and biotechnological approaches.

VI. **Theory**

Unit I

Historical aspect of heterosis, nomenclature and definitions of heterosis; Heterosis

in natural population and inbred population; Evolutionary aspects – Genetic consequences of selfing, sibbing and crossing in self-and cross-pollinated and asexually propagated crops; Pre-Mendelian and Post-Mendelian ideas – Evolutionary concepts of heterosis; Genetic theories of heterosis – Physiological, Biochemical and molecular factors underlining heterosis; theories and their estimation;Biometrical basis of heterosis.

Unit II

Prediction of heterosis from various crosses, inbreeding depression, coefficient of inbreeding and its estimation, residual heterosis in F_2 and segregating populations, importance of inbreeding in exploitation of heterosis – case studies.; Relationship between genetic distance and expression of heterosis, casestudies; Divergence and genetic distance analyses, morphological and moleculargenetic distance in predicting heterosis; Development of heterotic pools in germplasm/ genetic stocks and inbreeds, their improvement for increasing heterosis.

Unit III

Male sterility and use in heterosis breeding; Male sterile line creation and diversification in self-pollinated, cross pollinated and asexually propagated crops; Creation of male sterility through genetic engineering and its exploitation in heterosis; Maintenance, transfer and restoration of different types of male sterility; Use of self-incompatibility in development of hybrids.

Unit IV

Hybrid seed production system: 3-line, 2-line and 1-line system; Development of inbreeds and parental lines- A, B and R lines – functional male sterility; Commercial exploitation of heterosis, maintenance breeding of parental lines in hybrids; Fixation of heterosis in self, cross and often cross pollinated crops, asexually/ clonally propagated crops, problems and prospects; Apomixis in fixing heterosis-concept of single line hybrid; Organellar heterosis and complementation.

Unit V

Hybrid breeding in wheat, rice, cotton, maize, pearl millet, sorghum and rapeseed- mustard, sunflower, safflower and castor oilseed crops and pigeonpea.

VII. Practical

- Characterization of male sterile lines using morphological descriptors;
- Restorer line identification and diversification of male sterile sources;
- Male sterile line creation in crop plants, problems in creation of CGMS system,ways of overcoming them;
- Diversification and restoration;
- Success stories of hybrid breeding in Maize, Rice, Pearl millet, Sorghum and Pigeonpea;
- Understanding the difficulties in breeding apomicts;
- Estimation of heterotic parameters in self, cross and asexually

propagated crops;

- Estimation from the various models for heterosis parameters;
- Hybrid seed production in field crops—an account on the released hybrids, theirpotential, problems and ways of overcoming it;
- Hybrid breeding at National and International level,opportunities ahead.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completing this course, the student will be able to know about importance of heterosis, the various conventional and biotechnological approaches for the development of hybrids. This will also enable student to know about the use of male sterility in hybrid seed production of important field crops.

X. Suggested Reading

- Agarwal RL. 1998. *Fundamental of Plant Breeding and hybrid Seed Production*. Science Publisher London.
- Akin E. 1979. *The Geometry of Population Genetics*. Springer-Verlag.
- Ben HL. 1998. *Statistical Genomics – Linkage, Mapping and QTL Analysis*. CRC Press.
- Chal GS and Gossal SS. 2002. *Principles and procedures of Plant Breeding, Biotechnology and Convetional Approaches*. Narosa Publishing House. New Delhi
- De JG. 1988. *Population Genetics and Evolution*. Springer-Verlag. 30 January 2012 Hartl DL. 2000. *A Primer of Population Genetics*. 3rd Ed. Sinauer Assoc.
- Mettler LE and Gregg TG. 1969. *Population Genetics and Evolution*. Prentice-Hall. 25 April 1988
- Montgomery DC. 2001. *Design and Analysis of Experiments*. 5th Ed., Wiley & Sons. 2013 Mukherjee BK. 1995.*The Heterosis Phenomenon*. Kalyani Publishers, New Delhi.
- Proceedings of *Genetics and Exploitation of Heterosis in Crops* – An International Symposium CIMMYT, 1998.

- Richards AJ. 1986. *Plant Breeding Systems*. George Allen & Unwin. 30 May 1997 Singh BD. 2006. *Plant Breeding*. Kalyani Publishers, New Delhi.
- Srivastava S and Tyagi R. 1997. *Selected Problems in Genetics*. Vols. I, II. Anmol Publ. Virmani SS. 1994. *Heterosis and Hybrid Rice Breeding. Monographs of "Theoretical and Applied Genetics‖*, Springer-Verlag.

I. Course Title : Seed Production and Certification

II. Course Code : GPB 510

III. Credit Hours : 2(1+1)

IV. Why this course?

Seed is the essence of life. Its improvement, production and maintenance is an essential feature of any variety. Seed chain concept is highly relevant in commercial promotion of new varieties whereas process of certification is mandatory for qualityassurance of seed.

V. Aim of the course

To impart knowledge on principles of seed production and certification. This will help the students to understand seed production practices and seed certification procedures in different crops.

VI. Theory

Unit I

Importance of seed as basic input in agriculture; Seed quality concept and importance; Generation system of seed multiplication -Varietal replacement rate, Seed multiplication ratios, Seed replacement rate, Seed renewal period and seed demand

and supply; Various factors influencing seed production –Physical and Genetic purity in seed production; Factors responsible for varietal and genetic deterioration.

Unit II

Nucleus seed production and its maintenance - Maintenance of parental lines of hybrids, Production of breeder, foundation and certified seed and their quality maintenance; Principles of seed production in self- and cross-pollinated crops; Hybrid seed production - system and techniques involved in Seed village concept; Organicseed production and certification.

Unit III

Principles of seed production in field crops; Floral structure, pollination mechanism and seed production techniques in self- and cross-pollinated cereals and millets.

Unit IV

Floral structure, pollination mechanism and methods and techniques of seed production in major pulses and oilseed crops; Varietal and hybrid seed production techniques in Pigeon pea, Mustard, Castor and Sunflower.

Unit V

Floral structure, pollination mechanism and methods and techniques of seed production in major commercial fibres. Hybrid-seed production techniques in major vegetatively propagated crops.

Unit VI

Seed certification - history, concept, objectives;Central seed certification board Seed certification agency/ organization and staff requirement; Legal status - Phases of seed certification, formulation, revision and publication of seed certification standards; Minimum Seed Certification Standards (MSCS) for different crops - General and specific crop standards, Field and seed standards; Planning and management of seed certification programs; Eligibility of a variety for certification, area assessment, cropping history of the seed field.

VII. Practical

- Planting design for variety- hybrid seed production techniques, planting ratio of male and female lines, synchronization of parental lines and methods to achieve synchrony;
- Identification of rogues and pollen shedders, supplementarypollination, detasseling, hand emasculation and pollination;
- Pollen collection and storage methods, pollen viability and stigma receptivity;
- Pre-harvest sanitation, maturity symptoms, harvesting techniques;
- Visits to seed production plots - visit to seed industries;
- Planning for seed production: cost benefit ratio, seed multiplication ratio and seedreplacement rate;
- General procedure of seed certification, identification of weed and other crop seeds as per specific crops, field inspection at different stages of a crop and observations recorded on contaminants and reporting of results, inspection and sampling, harvesting/ threshing, processing and after processing for seed law enforcement;
- Specifications for tags and labels to be used for certification purpose.

VIII. Teaching methods

- Power point presentation

- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX.

X. Learning outcome

After completing this course the student will be able to know about seed production of different crop varieties and hybrids, their processing, marketing and seed laws.

XI. Suggested Reading

- Agrawal PK and Dadlani M. 1987. *Techniques in Seed Science and Technology*, South Asian Publishers, Delhi.
- Agrawal RL. 1997. *Seed Technology,* Oxford & IBH Publishing.
- Anon, 1965. *Field Inspection Manual and Minimum Seed Certification Standards*, NSCPublication, New Delhi.
- Anon. 1999. *Manual of Seed Certification procedures.* Directorate of Seed Certification, Coimbatore, Tamil Nadu.
- Joshi AK and Singh BD. 2004. *Seed Science and Technology*, Kalyani Publishers, New Delhi. Kelly AF. 1988. *Seed Production of Agricultural Crops*. John Wiley, New York.
- Mc Donald MB and Copeland LO. 1997. *Seed Science and Technology*, Scientific Publisher, Jodhpur.
- Ramamoorthy K, Sivasubramaniam K and Kannan M. 2006. *Seed Legislation in India*. Agrobios (India), Jodhpur, Rajasthan.
- Singhal NC. 2003. *Hybrid Seed Production in Field Crops*, Kalyani Publications, New Delhi Tunwar NS and Singh SV. 1988. *Indian Minimum Seed Certification Standards*. Central Seed Certification Board, Ministry of Agriculture, New Delhi.

e-Resources

www.gov.mb.ca www.agricoop.nic.in www.agri.nic.in www.fao.org www.seednet.gov.in

I.	**Course Title**	**: Crop Breeding I (*Kharif* Crops)**
II.	**Course Code**	**: GPB 511**
III.	**Credit Hours**	**: 3(2+1)**

IV. Why this course?

Botanical features, reproductive systems, genetics involved and important breeding techniques are essential to undertake any crop improvement programme. This course is designed for important/ major *Kharif* field crops.

V. Aim of the course

To provide insight into recent advances in improvement of kharif cereals, legumes, oilseeds, fibre, sugarcane and vegetative propagated crops using conventional and modern biotechnological approaches.

VI. Theory

Unit I

Rice: Origin, evolution, mode of reproduction, chromosome number; Genetics –

biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding,

released varieties, examples of MAS used for improvement, Aerobic rice, its

implications and drought resistance breeding.

Maize: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, releasedvarieties, examples of MAS used for improvement- QPM and Bt maize – strategies and implications.

Small millets: Evolution and distribution of species and forms - wild relatives and germplasm; Cytogenetics and genome relationship - breeding objectives yield, qualitycharacters, biotic and abiotic stress resistance, etc.

Unit II

Pigeon pea: evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement - Hybrid technology; maintenance of male sterile, fertile and restorer lines, progress made at National and International institutes.

Groundnut: Origin, evolution mode of reproduction, chromosome number; Genetics

– cytogenetics and genome relationship, breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Other pulses: Urdbean, mungbean, cowpea,: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship, breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), released varieties, examples of MAS used for improvement. Interspecific crosses attempted and its implications, reasons for failure, ways of overcoming them.

Unit III

Soybean: Origin, evolution, mode of reproduction, chromosome number; Genetics

– cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement. **Castor and Sesame**: Origin, evolution mode of reproduction, chromosome number; Genetics –cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), released varieties, examples of MAS used for improvement; Hybrid breeding in castor – opportunities, constraints andachievements.

Unit IV

Cotton: Origin, evolution, mode of reproduction, chromosome number; Genetics –

cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement, Development and maintenance of male sterile lines

– Hybrid development and seed production – Scenario of Bt cottons, evaluation procedures for Bt cotton.

Jute: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement.

Unit V

Sugarcane: Evolution and distribution of species and forms, wild relatives and germplasm; Cytogenetics and genome relationship – Breeding objectives-yield, quality characters, biotic and abiotic stress resistance, etc.

Forage crops: Evolution and distribution of species and forms – Wild relatives and germplasm; Cytogenetics and genome relationship; Breeding objectives-yield, quality characters and palatability studies; Biotic and abiotic stress resistance, etc. **Seed spices**: Origin, evolution, mode of reproduction, chromosome number; Genetics

– cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; Breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, Achievements of important spice crops.

VII. **Practical**

Floral biology, emasculation, pollination techniques in rice, maize, pigeon pea,soybean, sesame, cotton;

- Study of range of variation for yield and yield components;
- Study of segregating populations in cereal, pulses and oilseed crops;
- Learning on the crosses between different species; attempting crosses betweenblack gram and green gram;
- Evaluating the germplasm of cotton for yield, quality and resistance parameters,learning the procedures on development of Bt cotton;
- Visit to Cotton Technology Laboratory and Spinning Mills;
- Learning on the Standard Evaluation System (SES) and descriptors; Use of softwarefor database management and retrieval;
- Practical learning on the cultivation of fodder crop species on sewage water,analysing them for yield components and palatability;
- Laboratory analysis of forage crops for crude protein, digestibility percent andother quality attributes;
- Visit to animal feed producing factories;
- Learning the practice of value addition; Visiting the animal husbandry unit and learning the animal experiments related with palatability and digestibility of fodder.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completing this course, the student will be able to know about important botanical status and reproductive structures of crops and genetics of important kharif field crops.

X. Suggested Reading

- Agarwal RL. 1996. *Identifying Characteristics of Crop Varieties*. Oxford & IBH.
- Bahl PN and Salimath PM. 1996. *Genetics, Cytogenetics and Breeding of Crop Plants*. Vol. I. *Pulses and Oilseeds*. Oxford & IBH.
- Chandraratna MF. 1964. *Genetics and Breeding of Rice*. Longmans.
- Chopra VL and Prakash S. 2002. *Evolution and Adaptation of Cereal Crops*. Oxford & IBH. Gill KS. 1991. *Pearl Millet and its Improvement*. ICAR.
- IRRI. 1964. *Rice Genetics and Cytogenetics*. Elsevier.
- IRRI. 1986. *Rice Genetics*. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.
- IRRI. 1991. *Rice Genetics II*. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.
- IRRI. 1996. *Rice Genetics III*. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.
- IRRI. 2000. *Rice Genetics IV*. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.
- Jennings PR, Coffman WR and Kauffman HE. 1979. *Rice Improvement*. IRRI, Los Banos, Manila, Philippines.
- Kannaiyan S, Uthamasamy S, Theodore RK and Palaniswamy S. 2002. *New Dimensions and Approaches for Sustainable Agriculture*. Directorate of Extension Education, TNAU, Coimbatore.
- Murty DS, Tabo R and Ajayi O. 1994. *Sorghum Hybrid Seed*

Production and Management. ICRISAT, Patancheru, India.

- Nanda JS. 1997. *Manual on Rice Breeding*. Kalyani Publishers.
- Parthasarathy VA. 2017. *Spices and Plantation Crops Vol.1* (*Part A*) *Breeding of Horticultural Crops* Vol.1 (Part-B), Today and Tomorrow Printers and Publishers
- Poehlman, JM. 1987. *Breeding of Field Crops*. AVI Publishing Co. Inc. East Post Connecticut, USA.
- Ram HH and Singh HG. 1993. *Crop Breeding and Genetics*. Kalyani.
- Sharma, AK. 2005. *Breeding Technology of Crop Plant*. Yesh Publishing House, Bikaner Slafer GA. (Ed.). 1994. *Genetic Improvement of Field Crops*. Marcel Dekker.
- Singh HG, Mishra SN, Singh TB, Ram HH and Singh DP. (Eds.). 1994. *Crop Breeding in India*. International Book Distributing Co.
- Walden DB. 1978. *Maize Breeding and Genetics*. John Wiley & Sons.

I.	**Course Title**	: **Crop Breeding-II (*Rabi* Crops)**
II.	**Course Code**	: **GPB 512**
III.	**Credit Hours**	: **3(2+1)**

IV. Why this course?

Botanical features, reproductive systems, genetics involved and important breeding techniques are essential to undertake any crop improvement programme. This course is designed for important/ major Rabi field crops.

V. Aim of the course

To provide insight into recent advances in improvement of *Rabi* cereals, legumes, oilseeds, fibre and vegetative propagated crops using conventional andmodern biotechnological approaches

VI. Theory

Unit I

Wheat: Origin, evolution, mode of reproduction, chromosome number;Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement.

Oats: Origin, evolution, mode of reproduction, chromosome number; Genetics –

cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examplesof MAS used for improvement.

Barley: Origin, evolution, center of origin, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic andabiotic stress resistance, released varieties, examples of MAS used for improvement.

Unit II

Chickpea: Origin, evolution mode of reproduction, chromosome number; Genetics

– cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Other pulses: Lentil, field pea, Rajma, Horse gram: Origin, evolution, mode of reproduction, chromosome number; Genetics. cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement. Interspecific crosses attempted and its implications, reasonsfor failure, ways of overcoming them.

Unit III

Rapeseed and Mustard: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives; yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement, Oil quality, Improvement for oil quality.

Sunflower, Safflower: Origin, mode of reproduction, chromosome number; Genetics, cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, heterosis breeding, released varieties, examples of MAS used for improvement.

Unit IV

Mesta and minor fibre crops: Origin, mode of reproduction, chromosome number; Genetics–cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

Forage crops: Origin, evolution mode of reproduction, chromosome number; Genetics–cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance.

Unit V

Seed spices: Origin, evolution, mode of reproduction, chromosome number; Genetics– cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, scope of heterosis breeding, released varieties, examples of MAS used for crop improvement.

VII. Practical

- Floral biology, emasculation and pollination techniques in wheat, oats, barley,chickpea, rajma, rapeseed mustard, sunflower;
- Study of range of variation for yield and yield components;
- Study of segregating populations in cereal, pulses and oilseed crops;
- Use of descriptors for cataloguing; Learning on the crosses between different species;
- Trait based screening for stress resistance;
- Learning on the Standard Evaluation System (SES) and descriptors;
- Use of software for database management and retrieval.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the student will be able to know about the differentbreeding methods and genetics of major *Rabi* field crops.

X. **Suggested Reading**

- Agarwal RL. 1996. *Identifying Characteristics of Crop Varieties*. Oxford & IBH.
- Bahl PN and Salimath PM. 1996. *Genetics, Cytogenetics and Breeding of Crop Plants*. Vol. I. *Pulses and Oilseeds*. Oxford & IBH.
- Gupta SK. 2012. *Technological Innovations in Major World Oil crops*. Vol. I. Springer, USA. Gupta SK. 2012. *Technological Innovations in Major World Oil crops*. Vol. II. Springer, USA. Gupta SK. 2016. *Breedingof Oilseed Crops for Sustainable Production*. Academic Press, USA. Kannaiyan S, Uthamasamy S, Theodore RK and Palaniswamy S. 2002. *New Dimensions and*
- *Approaches for Sustainable Agriculture*. Directorate of Extension Education, TNAU, Coimbatore.
- Parthasarathy VA. 2017. *Spices and Plantation Crops* Vol.1 (Part A) *Breeding of Breeding and Genetics*. John Wiley & Sons.

I. **Course Title** : **Breeding Vegetable Crops**

II. **Course Code** : **GPB 513**

III. **Credit Hours** : **3(2+1)**

IV. **Why this course?**

This course enables the students to learn about breeding objectives, methodologies and genetics involved for the improvement of major vegetable crops.

V. **Aim of the course**

To educate about principles and practices adopted for breeding of vegetable crops.

VI. **Theory**

Unit I

Breeding for Leafy vegetables: Amaranth, chenopods and lettuce.

Unit II

Breeding for Cucurbits: Gourds, melons, pumpkins and squashes.

Unit III

Breeding for Solanaceae: Potato and tomato, eggplant, hot pepper, sweet pepper

Unit IV

Breeding for Cole crops: Cabbage, cauliflower, broccoli and knolkhol.

Breeding for Root vegetables: Carrot, beetroot, radish, sweet potato and tapioca.

Unit V

Breeding for other vegetable crops: Peas, beans, onion, garlic and okra.

VII. Practical

- Selection of desirable plants from breeding population, observations and analysisof various qualitative and quantitative traits in germplasm;
- Hybridization and handling segregating generations;
- Induction of flowering, palanological studies, selfing and crossing techniques invegetable crops;
- Hybrid seed production of vegetable crops in bulk;
- Screening techniques for insect-pests, disease and environmental stress resistance in vegetable crops;
- Demonstration of sib-mating and mixed population;
- Molecular marker techniques to identify useful traits in the vegetable crops andspecial breeding techniques;
- Visit to breeding blocks, MAS for incorporating traits governed by major andpolygenes.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the students will be able to know about the differentbreeding methods and genetics of major vegetable crops.

X. Suggested Reading

- Allard RW. 1999. *Principles of Plant Breeding*. John Wiley & Sons.
- Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable Crops: Breeding and Seed Production*. Vol. I. Kalyani Publishers, New Delhi.
- Kalloo G. 1988. *Vegetable Breeding*. Vols. I-III. CRC Press.
- Kalloo G. 1998. *Vegetable Breeding*. Vols. I-III (Combined Ed.). Panima

Edu. Book Agency. Peter KV and Pradeep KT. 2008. *Genetics and Breeding of Vegetables.* ICAR.

- Rai N and Rai M. 2006. *Heterosis Breeding in Vegetable Crops*. NewIndia Publication Agency. Ram HH. 2005. *Vegetable Breeding-Principles and Practices*. Kalyani Publishers
- Sharma JP. 2010. *Principles of Vegetable Breeding*. Kalyani Publishers, New Delhi. Singh BD. 1983. *Plant Breeding*. Kalyani Publishers

I. Course Title : Breeding Fruit Crops

II. Course Code : GPB 514

III. Credit Hours : 3(2+1)

IV. Why this course?

This course is aimed to educate the students about the breeding strategies andavenues in Fruit crops.

V. Aim of the course

To educate students about principles and practices adopted for breeding of fruitcrops.

VI. Theory

Unit I

Fruit crop breeding: History, importance of fruit breeding, centers of diversity, distribution, domestication and adaptation of commercially important fruits.

Unit II

Issues in fruit crop breeding – heterozygosity, polyploidy, polyembryony, parthenocarpy and seed lessness, incompatibility and sterility systems.

Unit III

Apomixis - merits and demerits, types, variability for economic traits, role of genetic engineering and biotechnology in improvement of fruit crops.

Unit IV

Crop improvement in Mango, Banana, Citrus, Grapes, Papaya, Sapota and Pomegranate, Pineapple and Guava, Apple and other Rosaceous crops andregion specific fruit crops.

VII. Practical

- Germplasm documentation;
- Floral biology of mango, guava, citrus, grape, pomegranate, pollen viability in major fruit crops;

- Pollen germination to study time of anthesis and stigma receptivity;
- Hybridization technique in important fruit crops, hybrid seed collection and raising;
- Colchicine treatment for induction of polyploidy;
- Exposure to resistance breeding and screening techniques;
- Mutation breeding practices raising and evaluation of segregating populations;
- Use of mutagens to induce mutations and polyploidy;
- Visit to Biotechnology Lab and study of *in-vitro* breeding techniques.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the students will be able do the breeding of fruit crops through various conventional and biotechnological methods besides mutation breeding.

X. Suggested Reading

- Bhojwani SS and Razdan MK. 2006. *Plant Tissue Culture -Theory and Practice*. Elsevier Publication, Amesterdam.
- Chadha KL and Pareek, OP. 1996. (Eds.). *Advances in Horticulture*. Vol. I to IV. Malhotra Publ. House, New Delhi.
- Chadha KL and Shikhamany SD. 1999. *The Grape: Improvement, Production and Post-Harvest Management*. Malhotra Publ. House, NewDelhi.
- Janick and Moore JN. 1996. *Advances in Fruit Breeding*, AVI Pub., USA. Janick J and Moore JN. 1996. *Fruit Breeding*. Vols. I to III. John Wiley & Sons.
- Kumar N. 2006. *Breeding of Horticultural Crops - Principles and Practices*. New India Publishing Agency, New Delhi.
- Moore JN and Janick Jules. 1996. *Methods in Fruit Breeding*. Purdue University Press, South Campus Court D., USA.
- Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK. and Mohanadas

S. 2001. *Biotechnology of Horticultural Crops.* Vols. I-III. Naya Prokash, Kolkata.

- Ray PK. 2002. *Breeding of Tropical and Sub-tropical Fruits*. Narosa Publishing House, New Delhi.
- Simmonds NW. 1976. *Evolution of Crop Plants,* Orient Longman, London.

I. Course Title : Breeding Ornamental Crops

II. Course Code : GPB 515

III. Credit Hours : 3(2+1)

IV. Why this course?

The course will impart knowledge to student about breeding of Ornamental Cropsthrough conventional and biotechnological interventions.

V. Aim of the course

To educate about principles and practices adopted for breeding of ornamental crops.

VI. Theory

Unit I

History of improvement of ornamental plants; Centre of origin of ornamental crop;Objectives and techniques in ornamental plant breeding.

Unit II

Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops, viz., Rose, Jasmine, *Chrysanthemum*, Tuberose, *Gerbera*, *Gladiolus*, *Dahlia*, *Lilium*, *Gaillardia*, *Petunia*, *Bouganvillea*, Pansy, Marigold, *Geranium*, *Antirrhinum*, China aster, Orchids, *Carnation*, *Hibiscus*, etc.

Unit III

Development of promising cultivars of important ornamental and flower crops; Role of Heterosis and its exploitation, production of F_1 hybrids and utilization of male sterility.

Unit IV

Production of open pollinated seeds, harvesting, processing and storage of seeds; Seed certification.

VII. Practical

- Study of floral biology and pollination in important species and cultivars of ornamental crops;

- Techniques of inducing polyploidy and mutation;
- Production of pure and hybrid seed;
- Methods of breeding suited to seed propagated plants;
- Polyploidy and mutations to evolve new varieties;
- Breeding methods for biotic and abiotic stresses;
- Visit to research institutes involved in ornamental crop breeding.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After completion of this course the students will be able to do the breeding of ornamental crops by conventional breeding and biotechnological methods and to know the genetics of major ornamental crops.

X. Suggested Reading

- Alexander V. 2002. *Breeding for ornamentals: Classical and Molecular Approaches*. Kluwer Academic Publishers, London.
- Allard RW. 1999. *Principles of Plant Breeding*. John Wiley & Sons. INC. New York. Bhattacharjee SK and De LC. 2003. *Advanced Commercial Floriculture* Vol. 1. Aavishkar Publishers & Distributors, Jaipur.
- Bose TK and Yadav LP. 2003. *Commercial Flowers*. Naya Prokash Publishers, Kolkata. Chadha KL and Bhattacharjee SK. *Advances in Horticulture* Vol. 12, Malhotra Publishing House, New Delhi.
- Mc Donald MB and Kwong FY. 2005. *Flower Seeds Biology and Technology*, CABI Publishing, Oxfordshire, UK.
- Watts L.1980. *Flower and Vegetable Plant Breeding*. Grower Books

I. Course Title : Breeding for Stress Resistance and Climate Change

II. Course Code : GPB 516

III. Credit Hours : 3(2+1)

IV. Why this course?

Climate change is a big challenge to sustain higher crop productivity and nutritionalquality. Concept of breeding for stress tolerance and development of hybrids/ varieties for climate change is of prime importance in plant breeding. Thereforethis course is essential for budding plant breeders.

V. Aim of the course

To apprise about various abiotic and biotic stresses influencing crop yield, mechanisms and genetics of resistance and methods to breed stress tolerant varieties.

VI. Theory

Unit I

Concept and impact of climatic change; Importance of plant breeding withspecial reference to biotic and abiotic stress resistance; Classification of biotic stresses – major pests and diseases of economically important crops.

Unit II

Concepts of resistance to insect and pathogen resistance; Analysis andinheritance of resistance variation; Host defence responses to pathogen invasions- Biochemical and molecular mechanisms; Acquired and induced immunity and systemic acquired resistance (SAR); Host-pathogen interaction, gene-for-gene hypothesis, molecular evidence for its operation and exceptions; Concept of signal transduction and other host-defence mechanisms against viruses and bacteria.

Unit III

Types and genetic mechanisms of resistance to biotic stresses –Horizontal and vertical resistance in crop plants; Quantitative resistance/ adult plant resistance and slow rusting resistance; Classical and molecular breeding methods - Measuring plant resistance using plant fitness; Behavioural, physiological and insect gain studies; Phenotypic screening methods for major pests and diseases; Recording of observations; Correlating the observations using marker data – Gene pyramiding methods and their implications. Classification of abiotic stresses - Stress inducing factors, moisture stress/ drought and water logging and submergence; Acidity, salinity/ alkalinity/ sodicity; High/low temperature, wind, etc.; Stress due to soil factors and mineral toxicity; Physiological and Phenological responses; Emphasis of abiotic stresses in developing breeding methodologies.

Unit IV

Genetics of abiotic stress resistance; Genes and genomics in breeding cultivars suitable to low water regimes and water logging and submergence, high and low/ freezing temperatures; Utilizing MAS procedures for identifying resistant types in important crops like rice, sorghum, wheat, cotton, etc.; Breeding for resistance to stresses caused by toxicity, deficiency and pollutants/ contaminants in soil, water and environment.

Unit V

Use of crop wild relatives as a source of resistance to biotic and abiotic factors in major field crops; Transgenics in management of biotic and abiotic stresses, use of toxins, protease inhibitors, lectins, chitinases and Bt for diseases and insect pest management.

VII. Practical

- Understanding the climatological parameters and predisposal of biotic and abiotic stress factors- ways of combating them for diseases caused by fungi and bacteria;
- Symptoms and data recording; use of MAS procedures;
- Phenotypic screening techniques for sucking pests and chewing pests – Traits tobe observed at plant and insect level;
- Phenotypic screening techniques for nematodes and borers; Ways of combatingthem;
- Evaluating the available populations like RIL, NIL, etc. for pest resistance;
- Use of standard MAS procedures. Breeding strategies - Weeds – ecological,environmental impacts on the crops;
- Breeding for herbicide resistance;
- Screening crops for drought and flood resistance; factors to be considered and breeding strategies;
- Screening varieties of major crops for acidity and alkalinity- their effects andbreeding strategies;
- Screening forage crops for resistance to sewage water and tannery effluents; Qualityparameters evaluation.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student’s presentations

IX. Learning outcome

After completion of this course the student will be able to well verse with the stress and its causes. This will enable the students for the developmentof RIL, NIL, etc.for pest resistance and Use of standard MAS procedures

X. Suggested Reading

- Blum A. 1988. *Plant Breeding for Stress Environments*. CRC Press.
- Christiansen MN and Lewis CF. 1982. *Breeding Plants for Less Favourable Environments*. Wiley International.
- Fritz RS and Simms EL. (Eds.). 1992. *Plant Resistance to Herbivores and Pathogens: Ecology, Evolution and Genetics*. The University of Chicago Press.
- Li PH and Sakai A. 1987. *Plant Cold Hardiness*. Liss, New York Springer
- Luginpill P. 1969. *Developing Resistant Plants - The Ideal Method of Controlling Insects*. USDA, ARS, Washington DC.
- Maxwell FG and Jennings PR. (Eds.). 1980. *Breeding Plants Resistant to Insects*. John Wiley & Sons. Wiley-Blackwell.
- Roberto F. 2018. *Plant Breeding for Biotic and Abiotic Stress Tolerance*. Springer. Russel GE. 1978. *Plant Breeding for Pest and Disease Resistance*. Butterworths. Sakai A and Larcher W. 1987. *Frost Survival in Plants*. Springer-Verlag.
- Singh BD. 2006. *Plant Breeding*. Kalyani Publishers, New Delhi. Turener NC and Kramer PJ. 1980. *Adaptation of Plants to Water and High Temperature Stress*. John Wiley & Sons.
- van der Plank JE. 1982. *Host-Pathogen Interactions in Plant Disease*. Academic Press**.**

I. Course Title : Germplasm Characterization and Evaluation

II. Course Code : GPB 517

III. Credit Hours : 2(1+1)

IV. Why this course ?

Students need to learn about morphological and quality agronomic traits of accessions as well as their reaction to biotic and abiotic stresses. This will increasethe importance of the germplasm.

V. Aim of the course

Students will gain knowledge on germplasm characterisation, evaluation and documentation of information. Recording of morphological and agronomic traits, including quality, as well as those for resilience to biotic and abiotic stresses thatwill promote utilisation. Exposure to development of web based tools for systematicdescription for efficient use of germplasm.

VI. **Theory**

Unit I

Understanding genetic diversity in crop plants; Crop descriptors, descriptorstates; germplasm characterization/ evaluation procedures; evaluation of germplasm for specific traits; Measuring diversity using agro-morphological data, statistical procedures to measure population genetic variation, markers and their use in PGR, evaluation of biotic and abiotic stresses, Principles and methods for formulating core and mini core collections and their validation, Web based tools for management of data.

Unit II

Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces, evaluation and maintenance of wild relatives of crop plants. Genetic enhancement, Use of CWRs genetic resources for crop improvement.

Unit III

High throughput phenotyping systems- imaging and image processing concepts for automated germplasm characterization (phenotyping) – evaluation for nutritional traits, resistance traits -Biochemical and molecular markers for characterization.

VII. **Practical**

- Field layout and experimental designs;
- Recording field data on germplasm evaluation in different agri-horticultural crops,
- post harvest handling;
- Evaluating quality traits, biochemical and phyto-chemical evaluation of crop germplasm, data processing;
- Documentation, analysis of diversity and cataloguing, data analysis, viability equations, sampling strategies, data documentation, cataloguing,biochemical analyses of samples.

VIII. **Teaching methods**

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. **Learning Outcome**

To educate students about science of managing genetic resources including principles involved in maintaining genetic integrity during regeneration, germplasm characterization and evaluation.

X. Suggested Reading

- Brown AHD, Clegg MT, Kahler AL, Weir BS (eds.) 1990. *Plant Population Genetics, Breeding, and Genetic Resources,* Sinauer Associates, USA.
- Frankel R and Galun E 1977. *Pollination Mechanisms, Reproduction and Plant Breeding. Monographs on Theoretical and Applied Genetics*, Springer-Verlag, Berlin, Heidelberg.
- Hayward MD, Bosemak NO and Romagosa I. 1993. *Plant Breeding: Principles and Practices,*Chapman & Hall.
- Holden JHN and Williams JT 1984. *Crop genetic resources: conservation and evaluation*, IBPGR. Puzone, L and Th. Hazekamp 1996. *Characterization and Documentation of Genetic Resources Utilizing Multimedia Database*. NBPGR, New Delhi.
- Rana RS, Sapra RL, Agrawal RC and Gambhir R 1991. Plant Genetic Resources, *Documentation and Information Management*. NBPGR, New Delhi.
- Stoskopf NC 1993. *Plant Breeding: Theory and Practice*, Westview Press.
- Sundeep Kumar, *et al.* 2016. *Evaluation of 19,460 wheat accessions conserved in the Indian national genebank to identify new sources of resistance to rust and spot blotch diseases*. PloS One Vol 11, pages 0167702.
- Tripathi K, Bhardwaj R, Bhalla S, Kaur V, Bansal R, Yadav R, Gangopadhyay KK, Kumar A and Chaudhury R. 2018. *Plant Genetic Resources Evaluation: Principles and Procedures*, Indian Council of Agricultural Research - National Bureau of Plant Genetic Resources (ICAR-NBPGR), New Delhi. vi+50 p.

I. Course Title : Genetic enhancement for PGR Utilization

II. Course Code : GPB 518

III. Credit Hours : 2(1+1)

IV. Why this course ?

Pre-breeding is a vital step in the link between plant genetic resources conservation and its use; Hence, this course is designed to inculcate theoretical and practical know how to understand and use classical and advanced plant breeding methodsfor planning and execution of prebreeding programmes so that the PGR is put into effective use for food and agriculture.

V. Aim of the course

To teach theoretical and practical know how on CWRs reproductive behavior, acclimatization and adaptation for utilization in prebreeding programmes usig advanced tools.

VI. Theory

Unit I

Concepts of gene pools; Introduction, potential of pre-breeding. Role of crop wild relatives, semi exotics, creating and managing variation, basic concepts to set upa successful pre-breeding programme.

Unit II

Understanding crop adaptation, handling and maintenance of CWRs, synchronization of flowering, overcoming impediments to flowering through photoperiodic adjustments, role of other barriers to flowering, role of amphidiploids, semi exotics and other unadapted germplasm, identifying desirable traits in natural populations, screening for biotic and abiotic stress resistance traits; screening of nutritionally important traits, genetic analysis to understand the inheritance of novel traits.

Unit III

Parental selection for prebreeding, search for superior genotypes, breeding methods for trait transfer; moving the genes - unadapted to adapted, wide hybridization, Incongruity and its management, modern tools for incongruity management, cytogenetical approaches for gene transfer such as alien addition and substitution, segregating populations and their management in wide crosses, purging the undesirable traits, testing and improving the adaptability of wide cross derivatives, cytological studies, florescence microscopy, embryo rescue methods, pollen physiology and storage, pollen storage methods to facilitate wide hybridization, pre- and post- zygotic barriers.

VII. Practical

- Characterization of CWRs by visiting the fields;
- Screening methods for special traits-biotic and abiotic resistance;
- Screening for nutritional traits;
- Crossability studies in CWRs of cereals, legumes, oilseeds, vegetables. Assessmentof pre and post-zygotic barriers in wide hybridization

crosses;

- Pollen storage studies;
- Special requirements for growing CWRs, inducing flowering by manipulating daylength, temperature, chemical spraying, etc.

VIII. Teaching methods

- Lectures
- Power point presentations
- assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

Students would be conversant with handling of unadapted germplasm, screening methods for special traits-biotic and abiotic resistance, nutritional traits, characterization of CWR, breeding, etc.

X. Suggested Reading

- Andey Pereira. 2006. *Plant Reverse Genetics*, Methods and Protocols, Humana Press
- Bisht *et al*. 2004. Broadening the genetic base of sesame (*Sesamum indicum* L.) through genetic enhancement. *Plant Genetic Resources* **2**(3): 143–151.
- Dale JW and von Schantz M. 2007. *From genes to genomes. Concepts and applications of DNA technology*. John Wiley & Sons Ltd., Chichester, England.
- Duvick DN. 1990. Genetic enhancement and plant breeding. p. 90–96. In: J. Janick and J.E. Simon (eds.), Advances in new crops. Timber Press, Portland.
- Goodman, RM. 2004. *Encyclopedia of plant and crop science*. Marcel Dekker Inc., Switzerland. Kimber, G and Feldman, M. 1987. *Wild Wheat: An introduction*. Special report 353, College of Agriculture, University of Missouri-Columbia.
- Lynch M. and Walsh B. 1998. *Genetics and analysis of quantitative traits*. Sinauer Associates Inc., MA, USA.
- Murphy D. 2007. *Plant breeding and biotechnology: Societal context and the future of agriculture*.
- Cambridge University Press, Cambridge, UK. Ram JS. 2010. *Plant Cytogenetics*. CRC Press.
- Ramanatha Rao V, Brown AHD, Jackson M. 2001. *Managing Plant*

Genetic Diversity. CABI publication.

- Sharma S, Upadhyaya HD, Varshney RK, *et al*. 2013. Pre-breeding for diversification of primary gene pool and genetic enhancement of grain legumes. *Front. Plant Sci*. **4**: 309.
- Yunbi Xu. 2010. Molecular plant breeding, CABI publishers

e-Resources

https://www.integratedbreedPlaning.net/ pre-breeding-effective-use-plant-genetic-resources http://www.croptrust.org/ http://www.bioversityinternational.org/training/training_materials/pre_breeding.htm http://www.grdc.com.au/director/research/prebreeding

I. Course Title : BREEDING OF TROPICAL CROPS
II. Course Code : GPB 519
III. Credit Hours : 2 (2+0)

IV. Why this course?

This course is aimed to educate the students about the breeding strategies and avenues in tropical crops with special relevance to Kerala conditions

V. Aim of the course

To provide insight into recent advances in improvement of perennial crops, tuber crops, spices, medicinal and aromatic plants using conventional and modern biotechnological approaches.

Theory

UNIT I

Perennial Commercial crops- Coconut, Arecanut, Rubber, Cashew, Cocoa, Coffee, Tea- Evolution and distribution of species and forms, wild relatives and germplasm, Classification, Cytogenetics, Breeding objectives – yield, biotic and abiotic stress resistance and quality, conventional and modern breeding approaches, achievements

UNIT II

Tropical tuber crops – Tapioca, Sweet potato, yam, colocasia: Evolution and distribution of species and forms, wild relatives and germplasm, Classification, Cytogenetics, Breeding objectives – yield, biotic and abiotic stress resistance and quality, conventional and modern breeding approaches, achievements

UNIT III

Spices - cardamom, black pepper clove, nutmeg, cinnamon, ginger, turmeric etc.

- Evolution and distribution of species and forms, wild relatives and germplasm, Classification, Cytogenetics, Breeding objectives – yield, biotic and abiotic stress resistance and quality, conventional and modern breeding approaches, achievements

UNIT IV

Medicinal and aromatic plants - Lemongrass eucalyptus *Oscimum*, *Piper longum*, *Kaempferia*, *Sida* spp. and other important tree medicinal plants Evolution and distribution of species and forms, wild relatives and germplasm, Classification, Cytogenetics, Breeding objectives – yield, biotic and abiotic stress resistance and quality, conventional and modern breeding approaches, achievements.

Suggested Readings

- Agarwal RL. 1996. *Identifying Characteristics of Crop Varieties*. Oxford & IBH.
- Bahl PN & Salimath PM. 1996. *Genetics, Cytogenetics and Breeding of Crop Plants*. Vol. I. *Pulses and Oilseeds*. Oxford & IBH.
- Kannaiyan S, Uthamasamy S, Theodore RK & Palaniswamy S. 2002. *NewDimensions and Approaches for Sustainable Agriculture*.Directorate of Extension Education,TNAU, Coimbatore.
- Ram HH & Singh HG. 1993. *Crop Breeding and Genetics*. Kalyani.
- Singh HG, Mishra SN, Singh TB, Ram HH & Singh DP. (Eds.). 1994.*Crop Breeding in India*. International Book Distributing Co.
- Chahal GS & Ghosal SS. 2002. *Principles and Procedures of Plant Breeding - Biotechnological and Conventional Approaches*. Narosa Publ.
- Chopra VL. 1997. *Plant Breeding*. Oxford & IBH. Nath V & Lal C. 1995. *Oilseeds inIndia*. Westvill Publ. House.
- Nigam J. 1996. *Genetic Improvement of Oilseed Crops*. Oxford & IBH.
- Ram HH & Singh HG. 1993. *Crop Breeding and Genetics*. Kalyani.
- Singh HG, Mishra SN, Singh TB, Ram HH & Singh DP. (Eds.). 1994. *Crop Breeding in India*. International Book Distributing Co.
- Mohan Jain S and Priyadarshan P M. 2009. Breeding Plantation Tree Crops- Tropical Species. Springer
- Bradshaw. J E. 2020. Root and Tuber Crops. Springer

VI. Course Title : Genetics
VII. Course Code : GP 520
VIII. Credit Hours : 2 (2+0)

20 GP 520 Genetics 2 + 0

Objectives

Offered for Agricultural Statistics students only

Theory

UNIT I

Physical basis of heredity–cell structures and functions-Cell divisions– mitosis, meiosisand their significance

UNIT II

Mendelian inheritance-application of statistical techniques in s ubstantiating Mendelian principles and modifications to Mendelian ratios like dominance,incomplete dominance, Epitasis.

UNIT III

Application of statistics in detecting linkage, crossing over, chromosome mappingetc.

UNIT IV

Quantitative traits-Multiple Factor Hypothesis-lethal genesUNIT V

Sex determination and sex linked characters and their identification through statisticaltechniques.

UNIT VI

Genetics of population-gene and genotype frequency – Hardy-Weinberg's law, itsderivation- forces changing gene frequency.

References

Genetics .2006 B D Singh Kalyani Publishers.Ludhiana

Genetics.2004.Verma P S and Aggarwal V K

Course Title with Credit Load for Ph.D. Genetics and Plant Breeding

Course Code	Course Title	Credit
GPB 601*	Advances in Plant Breeding Systems	3(3+0)
GPB 602	Advances in Biometrical Genetics	3(2+1)
GPB 603	Molecular Cytogenetics for Crop Improvement	2(2+0)
GPB 604	Plant Genetics Resources, Conservation and Utilization	2(2+0)
GPB 605*	Genomics in Plant Breeding	3(3+0)
GPB 606	Population Genetics	2(2+0)
GPB 607	Crop Evolution	3(3+0)
GPB 608	Breeding Designer Crops	2(1+1)
GPB 609*	IPR and Regulatory Mechanism (e-course)	1(1+0)
GPB 691	Doctoral Seminar I	0+1
GPB 692	Doctoral Seminar II	0+1
GPB 699	Doctoral Research	0+75

*Compulsory Major Courses

I. **Course Title** : **Advances in Plant Breeding Systems***

II. **Course Code** : **GPB 601**

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

IV. **Why this course?**

This course is an advancement of principles, various plant breeding methodologies and procedures in the development of a complex population; MAS for selection of qualitative and quantitative traits, Gene pyramiding, marker-based utilization of exotic Germplasm and introgression libraries.

V. **Aim of the course**

To impart theoretical knowledge about advances in plant breeding.

VI. **Theory**

Unit I

Advances in reproductive biology of crops; Genes governing the whorls formation and various models proposed; Pollen pistil interaction: biochemical and molecular basis, environmental factors governing anthesis and bottlenecks for gene transfer.

Unit II

Plant Breeding methodologies: Classic versus modern; Over view of Pre and Post Mendelian breeding methods in self and cross pollinated crops; Molecular and transgenic breeding approaches; doubled haploid breeding, shuttle breeding, forward and reverse breeding, speed breeding, participatory plant breeding, breeding for organic situations.

Unit III

Principles and procedures in the formation of a complex population; Genetic basis of population improvement in crop plants; Recurrent selection methods in self and cross pollinated crops and their modifications; Convergent selection, divergent selection; Recurrent selection, usefulness in hybrid breeding programs; Reciprocal recurrent selection; Selection in clonally propagated crops – Assumptions and realities.

Unit IV

Choice of molecular markers for plant breeding efficiency, fingerprinting and genetic diversity assessment, application of MAS for selection of qualitative and quantitative traits; Gene pyramiding, accelerated backcrossing, marker-based utilization of exotic germplasm, introgression libraries.

Unit V

Genetic resources: primary, secondary, tertiary and alien trans gene pool; Molecular and biochemical basis of self-incompatibility and male sterility, nucleocytoplasmic interactions with special reference to male sterility – genetic, biochemical and molecular bases.

Unit VI

Genetic engineering technologies to create male sterility, prospects and problems, use of self-incompatibility and sterility in plant breeding – case studies; Fertility restoration in male sterile lines and restorer diversification programs; Conversion of agronomically ideal genotypes into male sterile: Concepts and breeding strategies; Case studies - Generating new cyto- nuclear interaction system for diversification of male sterile; Stability of male sterile lines – Environmental influence on sterility, Environmentally Induced Genic Male Sterility (EGMS) – Types of EGMS; Influence on their expression, genetic studies; Photo and thermo sensitive genetic male sterilityand its use in heterosis breeding; Temperature sensitive genetic male sterility and its use heterosis breeding; Apomixis and its use in heterosis breeding; Incongruity: Factors influencing incongruity Methods to overcome incongruity mechanisms.

Unit VII

Breeding for climate change -Improving root systems, abiotic stress tolerance, water use efficiency, flooding and sub-mergence tolerance; Biotic stress tolerance; Nutrient use efficiency, nitrogen fixation and assimilation, greenhouse gases and carbonsequestration; Breeding for bio-fortification.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After completion of this course the student will be able to know variousplant breeding methodologies, principles and procedures for the formation of a complex population; MAS for selection of qualitative and quantitative traits, Gene pyramiding, marker based utilization of exotic Germplasm and Breeding for climate change

IX. Suggested Reading

- Agarwal RL. 1996. *Fundamentals of Plant Breeding and Hybrid Seed Production*. Oxford &IBH.

- Allard RW. 1966. *Principles of Plant Breeding*. John Wiley & Sons.
- Briggs FN and Knowles PF. 1967. *Introduction to Plant Breeding*. Reinhold.
- Fehr WR. 1987. *Principles of Cultivar Development: Theory and Technique*. Vol I. Macmillan. Hayes HK, Immer FR and Smith DC. 1955. *Methods of Plant Breeding*. McGraw-Hill.
- Kang MS and Priyadarshan PM (Edit.). 2007. *Breeding Major Food Staples*. Blackwell Publishing.
- Kole C. 2013. *Genomics and Breeding for Climate-Resilient Crops*. Springer. Volume 2-Target Traits.
- Mandal AK, Ganguli PK and Banerji SP. 1995. *Advances in Plant Breeding*. Vol. I, II. CBS. Richards AJ. 1986. *Plant Breeding Systems*. George Allen & Unwin.
- Sharma JR. 1994. *Principles and Practice of Plant Breeding*. Tata McGraw-Hill. Simmonds NW. 1979. *Principles of Crop Improvement*. Longman.
- Singh BD. 1997. *Plant Breeding: Principles and Methods*. 5th Ed., Kalyani Publishers, New Delhi.
- Singh P. 1996. *Essentials of Plant Breeding*. Kalyani Publishers, New Delhi. Welsh JR. 1981. *Fundamentals of Plant Genetic and Breeding*. John Wiley.

I. Course Title : Advances in Biometrical Genetics

II. Course Code : GPB 602

III. Credit Hours : 3(2+1)

IV. Why this course?

This course is essential to understand various qualitative, quantitative systems/ techniques related to genetic improvement of crops, G x E Interaction, Construction of saturated linkage maps and Marker Assisted Selection (MAS).

V. Aim of the course

To impart theoretical knowledge and computation methods for non-allelic interactions, mating designs and component analysis and their significance in plant breeding.

VI. Theory

Unit I

Continuous variation-evolutionary studies; Genetic principles of continuous variation, Qualitative and quantitative techniques-differences, population types, approaches;

various types of metrics, F_2, F□ and mixed; Selection of parents Simultaneous

selection models; Use of Multiple regression analysis in selection of genotypes.

Unit II

Components of mean- Additive effect, breeding value, coefficient of gene dispersion, dominance; Simple scaling test, expectation of mean of character in various types of families in coupling and dispersed phase; Epistasis-Specification, weighted and un-weighted joint scaling test; Effect of linkageto generation mean, specification of mean to G × E interaction.

Unit III

Component of variances-advantages, variances of different generations, balance sheet of variance; estimation of parameters-weighted and unweighted, least square analysis; random mating population; experimental population-BIPs, NCD-I, II, III, Triple test cross for random mating population and inbreds; Estimates of linkage and non-allelic interactions; Combining ability analysis, Hayman's Approach.

Unit IV

G × E Interaction, stability and adaptability; Advanced models in stability analysis - Pattern analysis - Additive Main Effect and Multiplicative Interaction (AMMI) analysis and other related models; Merits and limitation of different stability analysis methods; Analysis and selection of genotypes; Methods and steps to select the best model - Biplots and mapping genotypes.

Unit V

Construction of saturated linkage maps, concept of framework map development; QTLs-different types of markers and mapping populations, linkage maps, mapping- Strategies for QTL mapping - desired populations, statistical methods; MAGIC populations, Marker Assisted Selection (MAS) - Approaches to apply MAS in Plant breeding - selection based on markers - simultaneous selection based on markerand phenotype - Factors influencing MAS; Heritability of the trait, proportion of genetic variance, linkage disequilibrium between markers and traits and selection methods; Use of advanced software packages for biometrical analysis, interpretation of analysed data.

VII. Practical

- Generation mean analysis: ABC scaling test and Joint scaling test-Analysis andinterpretation;
- Estimation of variance of different filial generations and interpretations;
- Diallel analysis: Numerical, graphical and combining ability analysis; Triallelanalysis;
- NC Designs: Triple test cross analysis;
- Stability analysis: Eberhart and Russel model;
- AMMI model - Principal Component Analysis model - Additive and multiplicative model - Shifted multiplicative model - Analysis and selection of genotypes - Methods and steps to select the best model - Selection systems - Biplots and mapping genotypes;
- Construction of linkage maps and QTL mapping - Strategies for QTL mapping; statistical methods in QTL mapping;
- Phenotype and Marker linkage studies;
- Use of advanced software in biometrical analysis.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome

After the completion of this course student will be able to understand various Qualitative and quantitative techniques, G x E Interaction, Construction of saturatedlinkage maps and Marker Assisted Selection, Useof advanced software packages for biometrical analysis, interpretation of analysed data.

X. **Suggested Reading**

- Bos I and Caligari P. 1995. *Selection Methods in Plant Breeding*. Chapman & Hall. Dabholkar AR.1993. *Elements of Biometrical Genetics.* Concept Publishing Co. New Delhi. Falconer DS and Mackay J. 1996. *Introduction to Quantitative Genetics* (4 Ed.). ELBS/ Longman, London.
- Mather K and Jinks JL. 1985. *Biometrical Genetics* (3rd Ed.). Chapman and Hall, London.
- Nandarajan N and Gunasekaran M. 2008. *Quantitative Genetics and Biometrical Techniques in Plant Breeding.* Kalyani Publishers, New Delhi.
- Roy D. 2000. *Plant Breeding, Analysis and Exploitation of Variation*. Narosa Publishing House, New Delhi.
- Singh P and Narayanan SS. 1993. *Biometrical Techniques in Plant Breeding*. Kalyani Publishers, New Delhi.
- Singh RK and Choudhary BD. 1987. *Biometrical Methods in Quantitative Genetics*. Kalyani Publishers, New Delhi.
- Weir DS. 1990. *Genetic Data Analysis. Methods for Discrete Population Genetic Dat*a. Sinauer Associates.
- Wricke G and Weber WE. 1986. *Quantitative Genetics and Selection in Plant Breeding*. Walter de Gruyter.

I. Course Title : Molecular Cytogenetics for Crop Improvement
II. Course Code : GPB 603
III. Credit Hours : 2(2+0)

IV. Why this course?

This course is needed to understand organization and structure of genome, karyotyping, Pre-breeding and applications of cytogenetically methods for crop improvement

V. Aim of the course

This course focuses on applications of cytogenetic techniques for crop improvement.

VI. Theory

Unit I

Organization and structure of genome, Genome size, Organization of organellar genomes, Nuclear DNA organization, Nuclear and Cytoplasmic genome interactions and signal transduction; Inheritance and expression of organellar DNA; Variation in DNA content - C value paradox; Sequence complexity – Introns and Exons, Repetitive sequences, Role of repetitive sequence.

Unit II

Karyotyping – Chromosome banding and chromosome painting; Flow cytometry, chromosome walking Tracking introgressions using FISH, GISH, localization and mapping of genes/ genomic segments.

Unit III

Pre-breeding and applications of cytogenetical methods for crop improvement; Location and mapping of genes on chromosomes: deficiency method; Interchange genetic consequence, identification of chromosomes involved and gene location; balanced lethal systems, their maintenance and utility; Multiple interchanges-use in producing inbreds, transfer of genes-linked marker methods; Duplication - production and use; Inversions and location of genes; B/ A chromosome translocations and gene location.

Unit IV

Trisomics- types, production, breeding behavior and location of genes, use of balanced tertiary trisomics in hybrid seed production; Monosomics methods of production, breeding behavior and location of genes; Intervarietal substitutions-allelic and non- allelic interactions; Telocentric method of mapping, Production, cytogenetics and application of chromosome addition lines, substitution lines, chromosomal segment substitution lines (CSSLs).

Unit V

Cytogenomics: Concept, tools and techniques for crop improvement; Chromosome sorting: Isolation of specific chromosome for development of molecular maps and gene location.

Unit VI

Role of polyploidy in crop evolution and breeding. Auto- and allopolyploids; Distant hybridization, barriers to interspecific and intergeneric hybridization; Behaviour of interspecific and intergeneric crosses.

VII. Teaching methods

- Power point presentation
- Chalk and Board

- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning Outcome

After the completion of this course the student will be able to understand Organization and structure of genome, karyotyping, Pre-breeding, polyploidy and applications of cytogenetically methods for crop improvement.

IX. Suggested Reading

- Clark MS and Wall WJ. 1996. *Chromosomes: The Complex Code*. Chapman & Hall. 30 June 1996
- Conger BV. (Ed.). 1981. *Cloning Agricultural Plants via in-vitro Techniques*. CRC Press. 31 January 2018
- Constabel F and Vasil IK. (Eds.). 1988. *Cell Culture and Somatic Cell Genetics of Plants*. Vol.
- Cell Culture and Phytochemicals in Plant Cell Cultures. Academic Press. Gupta P K. 2006. *Cytogenetics*. Rastogi Publisher
- Lal R and Lal S. (Eds.). 1990. *Crop Improvement Utilizing Biotechnology*. CRC Press. Mantel SH and Smith H. 1983. *Plant Biotechnology*. Cambridge University Press.
- Sen SK and Giles KL. (Eds.). 1983. *Plant Cell Culture in Crop Improvement*. Plenum Press. 13 July 2013
- Yao-Shan F. 2002. *Molecular Cytogenetics: Protocols and Application*. Human Press

I. Course Title : Plant Genetic Resources, Conservation and Utilization

II. Course Code : GPB 604

III. Credit Hours : 2(2+0)

IV. Why this course?

This course is needed to make the student aware about the importance of PlantGenetic Resources its Conservation and Utilization in crop improvement.

V. Aim of the course

To impart knowledge on the methods of germplasm conservation and its utilization

VI. Theory

Unit I

Concept of natural reserves and natural gene banks; *In situ* conservation of wild species in nature reserves: *in situ* conservation components, factors influencing conservation value, national plan for *in situ* conservation; *in situ* conservation of agro-biodiversity on-farm; scientific basis of *in situ* conservation on-farm, building on-farm conservation initiatives, implementation of on-farm conservation, management of *in situ* conserved genetic diversity on- farm, enhancing benefits forfarmers from local crop diversity.

Unit II

Ex situ conservation: components, plant genetic resources conservation in gene banks, national gene banks, gene repositories, preservation of genetic materials under natural conditions, perma-frost conservation, guidelines for seed multiplication and exchange to network of active/ working collections, orthodox, recalcitrant seeds- differences in handling, clonal repositories, genetic stability under long term storage condition.

Unit III

In-vitro storage, maintenance of *in-vitro* culture under different conditions, *in-vitro* bank maintenance for temperate and tropical fruit crop species, spices, tubers, bulbous crops, medicinal and endangered plant species, conservation of embryos and ovules, cell/ suspension cultures, protoplast and callus cultures, pollen culture, micropropagation techniques, problems, prospects of *in-vitro*gene bank.

Unit IV

Cryopreservation- procedure for handling seeds of orthodox and recalcitrant- cryo- protectants, desiccation, rapid freezing, slow freezing, vitrification techniques, encapsulation/ dehydration techniques, national facilities, achievements, application of cryopreservation in agricultural, horticultural and forestry crops. Problems and prospects; challenges ahead.

Unit V

Concept and procedure for PGR management, germplasm characterization, evaluation and utilization; Concept of core and mini core; collections and registrationof plant germplasm.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion of this course the student will be able to know about the various techniques of conservation of Plant Genetic Resources and its Utilizationin crop improvement.

IX. Suggested Reading

- Ellis RH, Roberts EH and White Head J. 1980. *A New More Economic and Accurate Approach to Monitor the Viability of Accessions During Storage in Seed Banks*. FAO/ IBPGR Pl. Genet. Resources News 41-3-18.
- Frankel OH and Hawkes JG. 1975. *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press, Cambridge.
- Paroda RS and Arora RK.1991. *Plant Genetic resource Conservation and management*, NBPGR, New-Delhi.
- Simmonds NW. 1979. *Principles of Crop Improvement,* Longman.
- Westwood MN. 1986. *Operation Manual for National Clonal Germplasm Repository*. Processed Report. USDA-ARS and Oregon State Univ. Oregon, USA.
- Withers LA. 1980. *Tissue Culture Storage for Genetic Conservation*. IBPGR Tech. Rep. IBPGR, Rome, Italy.

I. Course Title : Genomics in Plant Breeding*
II. Course Code : GPB 605
III. Credit Hours : 3(3+0)

IV. Why this course?

The knowledge of recent trends in plant genomics, genome sequencing, molecular maps, and concepts of high-throughput proteomics, metabolomics and phenomics isessential in rapid crop improvement programmes.

V. **Aim of the course**

To impart practical skills in advanced molecular techniques in genome mappingstructural/ functional genomics.

VI. **Theory**

Unit I

Introduction to the plant genomes: nuclear, chloroplast and mitochondrial genomes; Concept of genome size and complexity: C-value paradox, repetitive and unique DNA.

Unit II

Genome sequencing: Principles and techniques of conventional approaches and next generation sequencing including sequencing-by-synthesis/ ligation and single molecule real time (SMRT) technologies; Applications of sequence information: structural, functional and comparative genomics; Plant genome projects: Strategiesfor genome sequencing including shot gun and clone-by- clone method.

Unit III

Molecular maps: Use of molecular markers/ SNPs for development of genetic and physical maps; Linkage and LD-based gene mapping approaches including gene/ QTL mapping, genome wide association studies (GWAS) and association analysis; Integration of genetic and physical map for map-based cloning of economically important genes. Concept of allele mining; Diversity array technology: conceptsand applications.

Unit IV

Functional genomics: concept of reverse and forward genetics; Use of activation tagging, transposon tagging, insertional mutagenesis, TILLING and ecoTILLING for crop improvement; Genome-wide and gene-specific transcriptomics approaches: serial analysis of gene expression, massively parallel signature sequencing, next generation sequencing, microarray, northern hybridization, RT-PCR, qRT-PCR andmolecular beacon.

Unit V

Development and management of database; Applications of bioinformatics tools/ software in genomics for crop improvement. Basic concepts of high- throughput proteomics, metabolomics and phenomics.

Unit VI

Recent transgene free genome editing tools such as CRISPR-Cas9 system, TALENS and ZFNs for crop improvement. Cisgenesis and Intragenesistools as twin sisters for Crop Improvement; Genomics-based plant breeding: Genome-Wide Genetic Diversity Studies, Identification of molecular markers linked to single Genes and QTL, Marker Assisted Selection (Marker Assisted Backcross Selection, Association mapping, Breeding by Design, Genome selection).

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion ofthis course, the student will have expertise on about different techniques for genome sequencing, molecular maps, and concepts of high-throughput proteomics, metabolomics and phenomics in crop improvement

IX. Suggested Reading

- Alonso JM, Stepanova AN. 2015. *Plant Functional Genomics: Methods and Protocols*. Springer. Chopra VL, Sharma RP, Bhat SR and Prasanna BM. 2007. *Search for New Genes*. Academic Foundation, New Delhi.
- Hackett PB, Fuchs JA and Messing JW. 1988. *An Introduction to Recombinant DNA Technology— Basic Experiments in Gene and Manipulation*. 2nd Ed. Benjamin Publication Co.
- Primose SB and Twyman RM. 2006. *Principles of Gene Manipulation and Genomics*. 7th Ed. Wiley-Blackwell Publishing.
- Sambrook J and Russel D. 2001. *Molecular Cloning - a Laboratory Manual*. 3rd Ed. Cold Spring Harbor Laboratory Press.
- Singh BD. 2005. *Biotechnology: Expanding Horizons*. Kalyani Publishers, New Delhi. Somers DJ, Langridge P, Gustafson JP. 2009. *Plant Genomics: Methods and Protocols*. Springer.

e-Resources

http://gramene.org https://www.arabidopsis.org https://wheat.pw.usda.gov http://ncbi.nlm.nih.gov http://www.maizegenetics.net

I. **Course Title** : **Population Genetics**

II. **Course Code** : **GPB 606**

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

IV. **Why this course?**

Population improvement programmes are the basis of genetic enhancementin cross pollinated crops. This course is needed to make the students aware about the population genetics and its role in crop improvement.

V. **Aim of the course**

To impart knowledge on structure, properties and their breeding values of different population.

VI. **Theory**

Unit I

Population: Properties of population, Mendelian population; Genetic constitution of a population through time, space, age structure, etc.; Frequencies of genes and genotypes; Causes of change: population size, differences in fertility and viability, migration and mutation.

Unit II

Hardy-Weinberg equilibrium, Hardy-Weinberg law, Proof and applications of theHardy-Weinberg law, Test of Hardy-Weinberg equilibrium; Mating frequencies:

Non-dominance, Codominance, Snyder's ratio, importance and its effect over random mating in succeeding generations.

Unit III

Multiple alleles, More than one locus, Sex linked genes; Use of gene and genotypic frequencies evaluation in field population level; Interpretations - Changes of gene frequency, Migration, Mutation, Recurrent and non-recurrent Selection; Balance between selection and mutation; Selection favoring heterozygotes; Overdominance for fitness.

Unit IV

Mating systems, Random mating population, Nonrandom mating: selfing – inbreeding coefficient, panmictic index, sibmating, Assortative mating and disassortative mating; Pedigree populations and close inbreeding, Estimation of linkage disequilibrium, Correlation between relatives and estimation of F; Effect of inbreeding and sibbing in cross pollinated crops; Gene substitution and average effects; Breeding value- Genetic drift; Genetic slippage, Co-adapted gene complexes; Homoeostasis- Adaptive organization of gene pools; Polymorphism- Balanced and Non-balanced polymorphism, heterozygous advantage- Survival of recessive and deleterious alleles in populations.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion of this course the student will be well versed with populationgenetics, its components and applications in crop improvement.

IX. Suggested Reading

- Chawla V and Yadava RK. 2006. *Principles of Population Genetics – A Practical Manual*. Dept. of Genetics, CCS HAU Hisar.
- Falconer DS and Mackay J. 1996. *Introduction to Quantitative Genetics*. Longman. Jain JP, Jain J and Parbhakaran VT. 1992. *Genetics of Populations*. South Asia Books. Li CC. 1955. *Population Genetics*. The Univ. of Chicago Press.
- Mather K and Jinks JL. 1982. *Biometrical Genetics*. Chapman & Hall.
- Sorrens D and Doniel G. 2007. *Methods in Quantitative Genetics*. Series: *Statistics for Biology and Health*. Likelihood.
- Tomar SS. 1992. *Text Book of Population Genetics*. Universal Pub.

I. Course Title : Crop Evolution
II. Course Code : GPB 607
III. Credit Hours : 3(3+0)

IV. Why this course?

This course imparts knowledge about the origin and evolution of species, centresof diversity, speciation, domestication and significance of polyploidy.

V. Aim of the course

To impart knowledge on crop evolutionary aspects and role of mutations, hybridizations and polyploidy in crop evolution and improvement.

VI. Theory

Unit I

Origin and evolution of species; Centres of diversity/ origin, diffusedcentres; Time and place of domestication; Patterns of evolution and domestication-examples and Case studies; Domestication and uniformity – Characteristics of early domestication and changes – Concept of gene pools and crop evolution; Selection and Genetic drift – Consequences.

Unit II

Speciation and domestication–The process of speciation, Reproductive isolation barriers; Genetic differentiation during speciation; Hybridization - speciation and extinction; Exploitation of natural variation: Early attempts to increase variation, Distant hybridization and introgression, Inter-specific, inter-generic hybridization, scope and limitations, techniques to overcome the limitations; Gene transfer into cultivated species, tools and techniques; Validation of transferred genes and their expression; Controlled introgressions.

Unit III

Processes in crop evolution and stabilization of polyploids, cytogenetic and genetic stabilization; Genome organization – Transgenesis in crop evolution, Multifactorial genome, Intragenomic interaction, Intergenomic interaction, Genome introgression; Methods to study crop evolution - Contemporary Methods, Based on morphological features, Cytogenetic analysis, Allozyme variations and crop evolution, DNA markers, genome analysis and comparative genomics.

Unit IV

Evolutionary significance of polyploidy, evolution of crop plants through ploidy manipulations; Polyploids: methods, use of autopolyploids; haploidy and DH-method of production and use, allopolyploids; synthesis of new crops; Case studies – Cereals, Pulses, Oilseeds, vegetables, Fibre crops, Plantation crops, Forage crops, Tuber crops, Medicinal Plants.

VII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

VIII. Learning outcome

After the completion of this course the student will have knowledge of Origin and evolution of species, Centres of diversity, Speciation, domestication and significance of micro-mutations and polyploidy in genetic improvement of crop plants.

IX. Suggested Reading

- Hancock JF. 2004. *Plant Evolution and the Origin of Crop Species*. 2nd Ed. CABI. Ladizinsky G. 1999. *Evolution and Domestication*. Springer.
- Miller AJ. 2007. *Crop Plants: Evolution*. John Wiley & Sons.
- Smartt J and Simmonds NW. 1995. *Evolution of Crop Plants*. Blackwell.

I. Course Title : Breeding Designer Crops
II. Course Code : GPB 608
III. Credit Hours : 2(1+1)

IV. Why this course?

This course enlightens about developing varieties for special traits, physiological efficiency and nutritional enhancement. It gives concept of biopharming and development of varieties producing targeted compounds, nutraceuticals and industrial products.

V. Aim of the course

Breeding crops for higher physiological efficiency and nutritional enhancement.

VI. Theory

Unit I

Breeding of crop ideotypes; Genetic manipulations through recombination breeding, genomics and transgenics for physiological efficiency, nutritional enhancement, special compounds-proteins, vaccines, gums, starch and fats.

Unit II

Physiological efficiency as a concept, parametric and whole plant physiology in integrated mode; Physiological mechanism of improvement in nutrient use efficiency, water use efficiency, osmotic adjustment, photosynthetic efficiency, stay green trait and its significance in crop improvement; Breeding for special traits, viz., oil, protein, vitamins, amino acids, etc.; Ecospecific ideotypes, Ideotypes for high and low moisture conditions, low and high input conditions, conversion mechanism of C_3 to C_4 plants; Determination of genetics of above mentioned traits.

Unit III

Improvement in yield potential under sub-optimal conditions by manipulating source and sink, canopy architecture, plant-water relationships, effect of suboptimal conditions on cardinal plant growth and development processes, enhancing input use efficiency through genetic manipulations.

Unit IV

Concept of biopharming and development of varieties producing targeted compounds, nutraceuticals and industrial products; Success stories in vaccines, modified sugars, gums and starch through biopharming.

Unit V

Biosafety management, segregation and isolation requirements in designer crop production and post-harvest management.

VII. Practical

- Demonstration of plant responses to stresses through recent techniques;
- Water use efficiency, transpiration efficiency, screening techniques under stress conditions such as electrolyte leakage, TTC, chlorophyll fluorescence, canopy temperature depression, stomatal conductance, chlorophyll estimation, heat/ drought/ salt shock proteins.

VIII. Teaching methods

- Power point presentation
- Chalk and Board
- Smart board
- Lectures
- Assignments, quiz
- Group tasks, student's presentations

IX. Learning outcome:

Pass outs will have clear understanding of ideotypes of crops under varied agro- climatic situations and breed for physiological efficient genotype. Can develop varieties for special traits having high therapeutic andnutracetrical value.

X. Suggested Reading

- Balint A. 1984. *Physiological Genetics of Agricultural Crops*. AK Ademiaikiado. Hay RK. 2006. *Physiology of Crop Yield*. 2nd Ed. Blackwell.
- Pessarakli M. 1995. *Handbook of Plant and Crop Physiology*. Marcel Dekker. Taiz L and Zeiger E. 2006. *Plant Physiology*. 4th Ed. Sinauer Associates.

I. **Course Title : IPR and Regulatory Mechanism (e-course)***

II. **Course Code : GPB 609**

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

IV. **Why this course?**

Biodiversity conservation and its judicious utilization are important in sustainable plant breeding programs. Breeders' and farmers' rights are important in scenarioof globalization of agriculture so knowledge of IPRs is essential for a plant breeder to protect his varieties.

V. **Aim of the course**

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.

VI. **Theory**

Historical perspectives and need for the introduction of Intellectual Property Rightregime; 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 otherbiological 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

VII. **Teaching methods**

- Power point presentation
- Smart board
- Assignments, quiz
- Group tasks, student's presentations

VIII. **Learning outcome**

The students will have acquaintance of intellectual property rights, national and international laws on biodiversity and sustainable use of plant genetic resources through transfer and sharing. Can assist in follow up of various treatises and laws for research collaborations at international levels.

IX. Suggested Reading

- Erbisch FH and Maredia K.1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
- Ganguli P. 2001. *Intellectual Property Rights: Unleashing Knowledge Economy*. McGraw-Hill.
- *Intellectual Property Rights: Key to New Wealth Generation. 2001*. NRDC & Aesthetic Technologies. Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer*. Vol. V. *Technology Generation and IPR Issues*. Academic Foundation.

SEED SCIENCE AND TECHNOLOGY

Course Title with Credit Load for M.Sc. in Seed Science and Technology

Course No.	Course Title	Credit hours
SST 501*	Seed Developmental Biology	2 (1+1)
SST 502	Seed Dormancy and Germination	2 (1+1)
SST 503*	Seed Production Principles and Techniques in Field Crops	3 (2+1)
SST 504*	Seed Production Principles and Techniques in Vegetable Crops	3 (2+1)
SST 505	Seed Production Techniques in Fruits, Flowers, Spices, Plantation and Medicinal Crops	3 (2+1)
SST 506	Seed Production Techniques in Forage, Pasture and Green Manure Crops	2 (1+1)
SST 507*	Seed Legislation and Certification	3 (2+1)
SST 508*	Post Harvest Handling and Storage of Seeds	3 (2+1)
SST 509*	Seed Quality Testing and Enhancement	2 (1+1)
SST 510	Seed Technology of Tree Species	2 (1+1)
SST 511	Seed Industry and Marketing Management	2 (1+1)
SST 512	Seed Health Testing and Management	2 (1+1)
SST 591	Master's Seminar	0+1
SST 599	Master's Research	0+30
	Total Credits	70

* Compulsory Courses

SST 501* Seed Developmental Biology 2 (1+1)

WHY THIS COURSE:

Seed is the most complex and successful unit of reproduction in flowering plants. Seed contains genetic wisdom of the past and act as an agent of genetic transfer from generation to generation. Basic knowledge on seed developmental biology will enable the learners to understand the structure of seed to take up research in seed science and technology.

OBJECTIVE

To acquire knowledge on the development and maturation of essential structures of seed and their influence on seed quality.

THEORY

Unit I:

Floral biology - types of pollination and pollination mechanisms - self-incompatibility and male sterility; sporogenesis - micro and mega sporogenesis; gametogenesis - development of male and female gametes and their structures; embryo plane formation, development of cotyledons and hard seed; pollination and fertilization - mode of pollination, double fertilization, factors affecting pollination and fertilization.

Unit II:

Embryogenesis - development of monocot and dicot embryos - development of endosperm and seed coat - types of endosperm; embryo plane formation, developmentof cotyledons - apomixis - identification, classification, significance and its utilization; parthenocarpy; poly-embryony - types and significance; haplontic and diplontic sterility system, causes of embryo abortion, embryo rescue technique; somatic embryogenesis.

Unit III:

Seed development - source of assimilates - mechanism of translocation; chemical composition - synthesis and deposition of storage reserves - starch, protein, fat and secondary metabolites - hormonal regulation - acquisition of seed dormancy and germination.

Unit IV:

Maturation drying - orthodox and recalcitrant seeds - desiccation tolerance mechanism - structural changes during desiccation - role of LEA proteins.

Unit V:

Seed maturity indices - physiological and harvestable maturity; biotic and abioticfactors influencing seed development - development of hard seeds.

PRACTICALS

Study on floral biology of monocots, dicots; pollen morphology - different crops,pollen germination, viability test in major crops; seed embryo and endosperm development in monocots, seed embryo and endosperm and cotyledon development in dicots; seed coat development - anatomy and morphology; development of hard seeds; external and internal seed structures; seed development and maturation - physical, physiological changes and biochemical changes in agricultural and horticultural crops; acquisition of seed dormancy and germination at different stages of maturity; physiological and harvestable maturity - indices in different crops ; Preparation of seed album - identification of seeds.

LECTURE SCHEDULE

1	Study of floral biology, types of pollination and mechanisms
2	Sporogenesis: microsporogenesis and megasporogenesis
3	Gametogenesis: development of male and female gametes and their structures
4	Pollination and fertilization: mode of pollination, double fertilization, factors affecting pollination and fertilization
5	Study of self-incompatibility and male sterility, Embryogenesis: development of monocot and dicot embryos
6	Development of endosperm and seed coat, types of endosperm embryo plane formation, development of cotyledons.
7	Apomixis : identification, classification, significance and its utilization
8	Mid semester examination
9	Polyembryony: types and significance; haplontic and diplontic sterility system
10	Causes of embryo abortion, embryo rescue technique; somatic embryogenesis.
11	Seed development: source of assimilates, mechanism of translocation; chemical composition
12	Synthesis and deposition of storage reserves - synthesis and deposition of starch and protein
13	Synthesis and deposition of fat and secondary metabolites ,hormonal regulation
14	Maturation drying: orthodox and recalcitrant seeds
15	Desiccation tolerance: mechanism, structural changes during desiccation and role of LEA protein
16	Seed maturity indices: physiological and harvestable maturity
17	Biotic and abiotic factors influencing seed development, development of hard seeds

PRACTICAL SCHEDULE

1	Study on floral biology of monocot plants
2	Study on floral biology of dicot plants

3 Study on pollen morphology of different crops
4 Pollen germination and viability test in major crops
5 Seed embryo and endosperm development in monocots
6 Seed embryo and cotyledon development in dicots
7 Anatomy and morphology of seed coat during development
8 Study on development of hard seeds
9 Study on external and internal seed structures
10 Seed development and maturation in agricultural crops - physical and physiological changes
11 Seed development and maturation in horticultural crops - physical and physiological changes
12 Study of biochemical changes during seed development and maturation in agricultural crops
13 Study of biochemical changes during seed development and maturation in horticultural crops
14 Study on acquisition of seed dormancy and germination at different stages of maturity
15 Study on physiological and harvestable maturity and maturity indices in different crops
16 Preparation of seed album and identification of seeds
17 Final Practical Examination

SUGGESTED READINGS

1 Adkins, S.W., Ashmore, S.E. and Navi, S.C. 2007. Seeds: Biology, Development and Ecology. CAB International, Oxfordshire, UK.
2 Frankel, R. and Galun, E. 1977. Pollination Mechanisms, Reproduction and Plant Breeding. Springer Verlag, New York.
3 Bewley, J.D., Black, M. 1994. Seeds: Physiology of Development and Germination. Springer, New York.
4 Copeland, L. O. and McDonald, M. B. 2001. Principles of Seed Science and Technology. 4th Ed. Kluwer Academic publishers, USA.
5 Black, M., Bewley, J. D. and Halmer, P. 2006. The Encyclopedia of Seeds: Science, Technology and Uses. CAB International publications, UK.
6 Chhabra, A. K. 2006. Practical Manual of Floral Biology of Crop Plants. Department of Plant Breeding, CCSHAU, Hisar.
7 Hesse, M. H., Haidemarie, R., Zettler, M., Webber, R., Buchner, A.R., Radivo and Ulrich, S. 2009. Pollen Terminology. An illustrated hand book. Springer Verlag, New York.
8 Kozlowski. T. T. 2012. Seed Biology: Importance, Development and Germination. (Vol. I). Academic Press Inc., New York.

9 Maiti, R.K., Sarkar, N.C. and Singh, V.P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.

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15 https://www.worldcat.org/title/seed-development-and-germination/oclc/44954614

16 https://books.google.co.in/books/about/Seeds.html?id=6S75Bw AAQBAJ & printsec = frontcover &s ource=kp_read_button & redir_esc=y#v =onepage&q&f=false

17 https://www.worldcat.org/title/seeds-ecology-biogeography-and-evolution-of-dormancy-and-germination/oclc/871225563

SUGGESTED WEBSITES

1 https://www.sciencedirect.com/book/9780124166776/seeds

2 http://www.seedbiology.de/structure.asp

3 http://www.fao.org/3/ad232e/AD232E02.htm

OUTCOME EXPECTED

- Successful completion of this course enable student to take up advanced research on seed developmental biology and understanding on fundamental aspects of gametogenesis, seed development and maturity.

SST 502 Seed Dormancy and Germination 2 (1+1)

WHY THIS COURSE:

Physiology and bio chemistry of dormancy and germination is basic science in the field of Seed Science and Technology. Complete understanding on the mechanisms of acquisition and release of dormancy and germination enable the students to take up research on advanced aspect which may helpful to design the seed for our requirement.

OBJECTIVE

To impart knowledge on significance, mechanism of dormancy, induction and release of seed dormancy and germination, types and factors influencing germination and their management.

THEORY

Unit I :

Seed dormancy - definition, concept and theories - significance - evolution; classification and mechanism of dormancy - ecological significance.

Unit II :

Induction of dormancy during development - hormonal, physiological, molecular and genetic control of dormancy - maternal and paternal contribution; environmental factors influencing dormancy induction and release - seasonal influence - winter and summer annuals - secondary dormancy induction mechanism; artificial induction of dormancy and release; soil seed bank - natural release of dormancy and its mechanism; dormancy breaking - principles and methods.

Unit III :

Seed germination - types and phases of germination; imbibition - pattern and water kinetics - events of germination - physical, physiological, biochemical changes; respiration - aerobic and anaerobic respiration during seed germination.

Unit IV :

Enzyme activation - mechanism - factors affecting enzyme activation - breakdown of stored materials - starch, protein and fat - energy generation - mobilization of storage reserves - changes in phenolic compounds.

Unit V :

Molecular and genetic control of seed germination- autotrophism; pattern of seed germination-tri phasic curve; factors affecting germination - media - temperature - light - gases; in-situ and viviparous germination - causes and mechanism.

PRACTICALS

Identification of types of seed dormancy - estimation of ABA and GA in dormant and non-dormant seeds - artificial induction of dormancy - dormancy breaking methods -

scarification, stratification,h ormonal and chemical treatment aafter-ripeningandleaching of inhibitors, combined treatments, assessing the duration for natural release of seed dormancy; seed germination - pattern of imbibition and seed germination - influence of light and temperature on germination and seedling development - hydrolytic enzyme analysis - changes in food reserves during seed germination.

LECTURE SCHEDULE

1	Definition, concept, theories and evolution of seed dormancy
2	Classification, mechanism and ecological significance of dormancy
3	Hormonal, physiological and molecular mechanism in induction of dormancy during development
4	Maternal and paternal contribution and genetic control of dormancy
5	Environmental factors influencing dormancy induction and release, seasonal influence on secondary dormancy induction mechanism
6	Artificial induction and release of dormancy, natural release of dormancy in soil seed bank and its mechanism
7	Dormancy breaking methods
8	Mid Semester Examination
9	Types, phases, imbibition pattern and water kinetics of seed germination
10	Physical, physiological and biochemical changes during seed germination
11	Aerobic and anaerobic respiration, enzyme activation, mechanism, factors affecting enzyme activation during seed germination
12	Breakdown of starch, protein and fat; ATP synthesis during seed germination
13	Mobilization of storage reserves during seed germination
14	Changes in phenolic compounds during seed germination
15	Molecular and genetic control of seed germination and autotrophism
16	Influence of media, temperature, light and gases on seed germination pattern of seed germination-tri phasic curve
17	Causes and mechanism of in-situ and viviparous germination

PRACTICAL SCHEDULE

1	Studies on seed dormancy and identification of types of dormancy
2	Estimation of ABA and GA in dormant and non-dormant seeds
3	Artificial induction of dormancy and release
4	Practicing scarification and stratification seed treatments

5 Practicing hormonal dormancy breaking treatments

6 Practicing chemical dormancy breaking treatments

7 Practicing combined dormancy breaking treatments

8 Assessing the duration of natural release of seed dormancy in soil seed bank

9 Studying the pattern of imbibition during seed germination

10 Studying the pattern of seed germination in different crops

11 Study on influence of light and temperature on germination and seedling development

12 Estimation of α-amylase during seed germination

13 Estimation of protease during seed germination

14 Estimation of lipase during seed germination

15 Estimation of dehydrogenase enzyme activity

16 Estimation of changes in food reserves during seed germination

17 Final Practical Examination

SUGGESTED READINGS

1 Baskin, C. and Baskin, J.M. (2014) Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination. Academic Press, Cambridge, UK.

2 Black, M. and Bewley, J.D. 2000. Seed Technology and its Biological Basis. CRC Press. Florida, USA.

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4 Heydecker, W. 1985. Seed Ecology. Pennsylvania State University Press, USA.

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8 Bewley, J.D., Bradford, K.J., Hilhorst, H.W.M. and Nanogaki, H. 2013. Seeds: Physiology of Development, Germination and Dormancy. Springer, New York.

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13 Bradbeer, J.W. 1988. Seed Dormancy and Germination. Chapman and Hall, New York, USA.

14 Prakash, M. 2011. Seed Physiology of Crops. Satish Serial Publishing house. Azadpur. New Delhi.

15 Maiti, R. K., Sarkar, N. C. and Singh, V. P. 2012. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur

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18 https://www.elsevier.com/books/seeds/baskin/978-0-12-416677-6

19 https://books.google.co.in/books/about/Physiology_ and_Biochemistry_ of_ Seeds_ in.html?id=9 1nsCAAAQBAJ&printsec =frontcover&source= kp_read_ button&redir_esc=y#v=onepage&q&f=false

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21 https://books.google.co.in/books/about/Seed_Dormancy_and_Germination .html?id= 18HeBwAAQBAJ&printsec =frontcove r&s ource=kp_read_button&redi r_esc=y#v=onepage&q&f=false

SUGGESTED WEBSITES

1 https://agriinfo.in/botany/18/

2 https:/sproutnet.com/seed-dormancy/

3 https://www.britannica.com/science/germination

4 http://www.biologyreference.com/Re-Se/Seed-Germination-and-Dormancy.html

5 https://www.intechopen.com/books/advances-in-seed-biology/seed-dormancy

OUTCOME EXPECTED

- By learning this course, students will understand the fundamental theories and mechanism underlying in seed dormancy and germination which will be useful for both basic research and development.

SST 503* Seed Production Principles and Techniques in Field Crops 3 (2+1)

WHY THIS COURSE:

Awareness about the use of quality seed among farmers to enhances the seed demand and seed trade. To meet the seed demand, production should be carried out in large areas. Hence, it is essential to learn about the production principles and techniques of quality seed production.

OBJECTIVE

To impart knowledge on principles and practices involved in quality seed production of field crops.

THEORY

Unit I :

Importance of seed - seed quality - concept - factors influencing seed production; classes of seed - generation system of seed multiplication - stages of seed multiplication in varieties and hybrids - seed multiplication ratio (SMR) - seed replacement rate (SRR) - seed renewal period (SRP) - varietal replacement rate (VRR).

Unit II :

Genetic and agronomic principles of variety and hybrid seed production; nucleus and breeder seed production techniques and their maintenance; methods and techniques of seed production in varieties and hybrids of important cereals and millets - wheat, oat, rice, maize, sorghum and pearl millet; varietal seed production in small millets - finger millet, fox tail millet, little millet, kodo millet, proso millet and barnyard millet. Physical purity and genetic purity analysis in Field crops and Mid storage correction in field crops

Unit III :

Methods and techniques of varietal seed production in major pulses - black gram, green gram, cowpea, chickpea, horse gram, soybean and lentil - varietal and hybrid seed production in red gram.

Unit IV :

Methods and techniques of seed production in major oil seed crops - groundnut, sesame - varietal and hybrid seed production in sunflower, castor and mustard; varietal seed production in minor oilseed crops (safflower, linseed, niger) - varietal and hybrid seed production in cotton - varietal seed production in jute; seed and planting material production techniques in sugarcane.

Unit V :

Seed production planning for selection of varieties and hybrids of major crops; farmer's participatory seed production - seed hubs, seed village concept and community seed bank.

PRACTICALS

Criteria for seed selection on field establishment - sowing and nursery management techniques -Physical purity and genetic purity analysis in Field crops and Mid storage correction in field crops - seedling age on crop establishment , rice and pearl millet-isolation distance - space and barrier isolation : modifying isolation based on border rows in maize - planting design for hybrid seed production, rice maize , pearl millet , cotton , redgram ,sunflower- detasseling, emasculation and dusting - methods of achieving synchronization rice, bajra, sunflower- practising supplementary pollination, rice and sunflower - identification of off-types - roguing operation - estimation of seed shattering loss; in-situ germination and loss; visit to seed production fields; visit to seed industry and seed production field.

LECTURE SCHEDULE

1	Seed and its importance in agriculture and concept of seed quality
2	Biotic and abiotic factors influencing seed production
3	Different classes of seed and generation system of seed multiplication
4	Stages of seed multiplication and maintenance of parental lines in hybrids
5	Seed Multiplication Ratio (SMR) and Seed Replacement Rate (SRR) and their significance
6	Seed Renewal Period (SRP) and Varietal Replacement Rate (VRR) and their significance
7	Genetic and agronomic principles of variety and hybrid seed production
8	Nucleus seed production techniques and its maintenance
9	Breeder seed production techniques and its maintenance
10	Principles and techniques of seed production in varieties and hybrids of wheat and oat
11	Principles and techniques of seed production in rice varieties
12	Principles and techniques of seed production in rice hybrids
13	Principles and techniques of seed production in maize varieties and hybrids
14	Principles and techniques of seed production in varieties and hybrids of sorghum and pearl millet
15	Principles and techniques of varietal seed production in small millets - finger millet, fox tail millet and little millet
16	Physical purity and genetic purity analysis in Field crops and Mid storage correction in field crops
17	Mid - Semester Examination

18 Principles and techniques of varietal seed production in small millets - kodo millet, proso millet and barnyard millet
19 Principles and techniques of seed production in black gram, green gram and cowpea varieties
20 Principles and techniques of varietal seed production in chickpea and horse gram
21 Principles and techniques of varietal seed production in soybean and lentil
22 Principles and techniques of varietal and hybrid seed production in red gram
23 Principles and techniques of varietal seed production in groundnut
24 Principles and techniques of varietal seed production in sesame
25 Principles and techniques of varietal and hybrid seed production in sunflower
26 Principles and techniques of varietal and hybrid seed production in castor
27 Principles and techniques of varietal and hybrid seed production in mustard
28 Principles and techniques of varietal seed production in minor oilseed crops - safflower, linseed and niger
29 Principles and techniques of varietal and hybrid seed production in cotton
30 Principles and techniques of varietal seed production in jute
31 Seed and planting material production techniques in sugarcane
32 Seed production planning for selection of varieties and hybrids of major crops
33 Farmers participatory seed production through seed hubs and seed village concept
34 Role of community seed bank in India

PRACTICAL SCHEDULE

1 Selection criteria for quality seed and its effect on field establishment
2 Practicing sowing and nursery management techniques
3 Study on the effect of seedling age on crop establishment in rice and pearl millet
4 Study on space and barrier isolation for seed production
5 Planting design for hybrid seed production in rice, maize and pearl millet
6 Planting design for hybrid seed production in cotton, red gram and sunflower
7 Practicing detasseling technique for hybrid seed production in maize
8 Practicing emasculation and dusting for hybrid seed production in cotton
9 Study on methods of achieving synchronization in rice, bajra and sunflower
10 Practicing supplementary pollination in rice and sunflower
11 Identification of off types - pollen shedders, shedding tassels, partials, selfed bolls and practicing roguing operation
12 Estimation of seed shattering loss and study on in-situ germination
13 Visit to seed production fields and Visit to seed industry

14 Physical purity and genetic purity analysis in Field crops and Mid storage correction in field crops

15 Seed production planning for varieties and hybrids

16 Economics of varietal and hybrid seed production

17 Final practical examination

SUGGESTED READINGS

1 Singhal, N. C. 2003. Hybrid Seed Production in Field Crops. Kalyani Publications, New Delhi.

2 Joshi, A. K. and Singh, B. D. 2004. Seed Science and Technology. Kalyani Publishers, New Delhi.

3 Kulkarni, G. N. 2011. Principles of Seed Technology. Kalyani Publishers, New Delhi.

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5 Sen, S. and Ghosh, N. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.

6 Mondal, S.S., Saha, M. and Sengupta, K. 2009. Seed Production of Field Crops. New India Publishing Agency, New Delhi.

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10 Maiti, R.K., Sarkar, N.C. and Singh, V.P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.

11 Chowdhury, R.K. and Lal, S.K. 2003. Nucleus and breeder seed production manual, National Seed Project (Crops), ICAR, New Delhi.

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14 https://www.nipabooks.com/info/9788190723763/seed-production-of-field-crops

15 https://www.amazon.in/Production-Field-Crops-Brajesh-Tiwari/dp/9380179405

SUGGESTED WEBSITES

1 https://agriinfo.in/botany/18/

2 http://www.fao.org/3/a-e8935e.pdf

3 http://www.agriquest.info/seed_production.php

4 http://agritech.tnau.ac.in/seed_certification/seedtech_index.html

5 http://coin.fao.org/coinstatic/cms/media/16/13666518481740/seed_ enterprises_ enhacement_and_development_project_in_sierra_leone_mission_1_report_.pdf

OUTCOME EXPECTED

- Successful completion of this course enable student to take up seed production venture in scientific manner to ensure seed quality and profitability.

SST 504* Seed Production Principles and Techniques in Vegetable Crops3 (2+1)

WHY THIS COURSE:

Seed trade is mainly based on high value low volume seeds. Area under vegetable cultivation is increasing day by day, which demands high area under seed production. The thorough knowledge on vegetable seed production will enable the students to take up seed production venture in low volume high value crops.

OBJECTIVE

To impart knowledge on principles and practices involved in quality seed production of vegetable crops.

THEORY

Unit I :

Importance and present status of vegetable seed industry - principles of seed production in vegetable crops - genetic, agronomic principles - factors influencing vegetable seed production - seed multiplication ratio and seed replacement rate; varietal and hybrid seed production techniques in major solanaceous vegetable crops - tomato, brinjal, chilli and sweet pepper; malvaceous vegetable crop - bhendi.

Unit II :

Varietal and hybrid seed production techniques in cucurbitaceous vegetables - bitter gourd, ridge gourd, snake gourd, bottle gourd, ash gourd, pumpkin, water melon, musk melon and cucumber; cole crops - cauliflower, cabbage, Chinese cabbage, broccoli, Brussle’s sprout.

Unit III :

Varietal and hybrid seed production techniques in root vegetables - carrot, beetroot, turnip, radish and knol-khol; seed production techniques in major leguminous vegetables - lab lab, cluster bean, vegetable cowpea, peas and beans.

Unit IV :

Seed production techniques in leafy vegetables - amaranthus, palak, spinach, celery, lettuce,; seed production techniques in onion and TPS.

Unit V :

Clonal multiplication techniques - potato - seed tubers, mini and micro tubers, sweet potato, tapioca, colocasia and yam - clonal standards; merits and demerits; clonal degeneration;techniques of seed production under protected cultivation.

PRACTICALS

Internal and external structure of vegetable seeds - floral biology of vegetable crops; preparation of nurseries and practicing sowing methods - practising the minisett techniques in tapioca, amorphophallus and yams - effect of age of seedlings on crop establishment - emasculation and pollination methods - identification of off-types - practicing roguing operations - physiological maturity indices in vegetable crops - seed extraction methods - maturity stages on seed quality characters - different pickings on seed quality - visit to vegetable seed production fields - visit to private seed industry - seed production planning for varieties and hybrid vegetables - economics of varietal and hybrid seed production in vegetables.

LECTURE SCHEDULE

1	Importance and present status of vegetable seed industry
2	Genetic and agronomic principles of seed production in vegetable crops
3	Factors influencing vegetable seed production
4	Seed multiplication ratio and seed replacement rate in vegetable crops
5	Principles and methods of varietal and hybrid seed production techniques in tomato and brinjal
6	Principles and methods of varietal and hybrid seed production techniques in chilli and sweet pepper
7	Principles and methods of varietal and hybrid seed production techniques in bhendi
8	Principles and methods of varietal and hybrid seed production techniques in bitter gourd and ridge gourd
9	Principles and methods of varietal and hybrid seed production techniques in snake gourd and bottle gourd
10	Principles and methods of varietal and hybrid seed production techniques in ash gourd and pumpkin
11	Principles and methods of varietal and hybrid seed production techniques in water melon and musk melon
12	Principles and methods of varietal and hybrid seed production techniques in cucumber
13	Principles and methods of varietal and hybrid seed production techniques in cauliflower

14 Principles and methods of varietal and hybrid seed production techniques in cabbage and Chinese cabbage.

15 Principles and methods of varietal and hybrid seed production techniques in broccoli and Brussle's sprout.

16 Principles and methods of varietal and hybrid seed production techniques in carrot and beetroot

17 Mid-semester examination

18 Principles and methods of varietal and hybrid seed production techniques in turnip and radish

19 Principles and methods of varietal and hybrid seed production techniques in knol-khol

20 Techniques of seed production in lab-lab and cluster bean

21 Techniques of seed production in vegetable cowpea, peas and beans

22 Seed production techniques in amaranthus and palak

23 Seed production techniques in spinach and celery

24 Techniques of seed production in lettuce

25 Seed production techniques in black nightshade and lamb's quarters

26 Seed production techniques in moringa

27 Techniques of seed production in onion

28 True potato seed production technique

29 Production of mini and micro seed tubers in potato through clonal multiplication techniques

30 Clonal multiplication techniques in sweet potato

31 Clonal multiplication techniques in tapioca

32 Clonal multiplication techniques in colocasia and yam

33 Clonal standards, merits and demerits of clonal multiplication techniques, clonal degeneration

34 Seed production techniques under protected cultivation

PRACTICAL SCHEDULE

1 Study of internal and external structure of vegetable seeds

2 Studying floral biology of solanceous and malvaceous

3 Studying floral biology of cucurbitaceous and leguminous vegetable crops

4 Preparation of nurseries and practicing sowing methods

5 Studying the effect of age of seedlings on crop establishment

6 Practicing emasculation and pollination methods

7 Identification of off-types, selfed fruits and practicing roguing operations

8 Identification of physiological maturity indices in vegetable crops

9 Practicing wet seed extraction methods - tomato, brinjal, bitter gourd, bottle gourd, ash gourd, pumpkin, water melon, musk melon and cucumber

10 Practicing dry seed extraction methods - chilli, bhendi, ridge gourd and bottle gourd

11 Study on the effect of maturity stages on seed quality characters

12 Studying the effect of different pickings on seed quality

13 Practising the minisett techniques in tapioca, amorphophallus and yams

14 Visit to private seed industry and Visit to vegetable seed production fields

15 Seed production planning for varieties and hybrid vegetables

16 Economics of varietal and hybrid seed production in vegetables

17 Final practical examination

SUGGESTED READINGS

1 Kulkarni, G. N. 2011. Principles of Seed Technology. Kalyani Publishers, New Delhi.

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12 http://www.worldseed.org/wp-content/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf

13 https://trove.nla.gov.au/work/6862691?q&sort=holdings+desc&-=1541066209257&versionId=45008917+251246346

SUGGESTED WEBSITES

1 https://agriinfo.in/botany/18/

2 http://agritech.tnau.ac.in/seed_certification/seedtech_index.html

3 https://www.hort.vt.edu/Welbaum/seedproduction/Principles5.html

4 http://www.agrimoon.com/wp-content/uploads/Seed-Production-of-Vegetable.pdf

5 http://www.ciks.org/downloads/seeds/4.%20Seed%20Production%20Techniques%20 for%20Vegetables.pdf

OUTCOME EXPECTED

- Successful completion of this course enable student to gain confidence and to become seed entrepreneur in high value low volume vegetable crops.

SST 505 Seed Production Techniques in Fruits, Flowers, Spices, Plantation and Medicinal Crops 3 (2+1)

WHY THIS COURSE:

At present seed industry is expanding towards the low volume and high value seeds. Domestication of fruit, plantation and medicinal plants enable the farmers to cultivate commercially. The seed demands in these crops are increasing day by day. Hence, it is essential to learn the techniques of seed production in fruits, flowers and plantation crops.

OBJECTIVE

To impart comprehensive knowledge on seed production techniques in fruits, flowers, spices, plantation and medicinal crops.

THEORY

Unit I :

Scope for seed production in fruits, flowers, spices, plantation and medicinal crops; factors influencing seed production and quality; propagation methods - seed and clonal propagation; seed and seedling standards; propagation and seed production techniques in major tropical and sub-tropical fruit crops - papaya, mango, citrus, amla, avocado, sapota and banana.

Unit II :

Seed production techniques in commercially important flower crops - petunia, marigold, zinnia, gaillardia, cock's comb, china aster, gomphrena, chrysanthemum, crossandra and balsam - nursery management, clonal propagation, planting, seed crop management, post-harvest seed handling and storage techniques.

Unit III :

Seed production techniques in important spices - coriander, fenugreek, fennel, curry leaf, nutmeg, cinnamon, turmeric, ginger, garlic, pepper and cardamom - nursery management, sowing, seed crop management and post-harvest seed handling and storage techniques.

Unit IV :

Seed production in important plantation crops – coffee, tea, cocoa, rubber, cashew, coconut, arecanut, oil palm and palmyrah - mother tree selection - criteria - nursery management, elite seedling production, planting, plantation management, post-harvest handling and storage techniques.

Unit V :

Methods of quality seed production in important medicinal plants - aswagantha, babchi, phyllanthus, kalmegh, senna, periwinkle, basil, Thipalli, Sida, and mint- nursery management, sowing, seed crop management, post-harvest handling and storage methods.

PRACTICALS

Floral biology and pollination mechanism - collection and identification of seeds of fruits, flowers, spices, plantation and medicinal crops - selection of mother plants - selection of seed nuts and planting methods for elite seedling production in coconut, arecanut and palmyrah - seed germination enhancement techniques in fruits, spices, plantation crops, flowers, medicinal crops - selection of planting materials and sowing methods - nursery management practices for elite seedling production - seed extraction methods - seed grading and upgrading techniques - seed handling and storage techniques of recalcitrant seeds - planning for seed production - economics of seed production in flower crops - visit to mother plant orchard - visit to medicinal garden.

LECTURE SCHEDULE

1	Scope and importance of seed production in fruits, flowers, spices, plantation and medicinal crops
2	Factors influencing seed production in fruits, flowers, spices, plantation and medicinal crops
3	Propagation methods in fruits, flowers, spices, plantation and medicinal crops
4	Seed and seedling standards for fruits, flowers, spices, plantation and medicinal crops
5	Seed production, post-harvest handling and storage techniques in papaya

6 Seed handling techniques in mango

7 Seed handling techniques in citrus

8 Seed handling techniques in amla

9 Seed handling techniques in avacado

10 Seed handling techniques in sapota and banana

11 Seed production, post-harvest handling and storage techniques in petunia and marigold

12 Seed production, post-harvest handling and storage techniques in zinnia and gaillardia

13 Seed production, post-harvest handling and storage techniques in cock's comb and china aster

14 Seed production, post-harvest handling and storage techniques in gomphrena and chrysanthemum

15 Seed production, post-harvest handling and storage techniques in crossandra and balsam

16 Seed production, post-harvest handling and storage techniques in coriander and fenugreek

17 Mid-Semester Examination

18 Seed production, post-harvest handling and storage methods in fennel and curry leaf

19 Clonal seed production, post-harvest handling and storage methods in nutmeg and cinnamon

20 Clonal seed production, post-harvest handling and storage methods in turmeric garlic and ginger

21 Clonal seed production, post-harvest handling and storage methods in pepper and cardamom

22 Seed and clonal propagation methods, post-harvest handling and storage techniques in coffee and tea

23 Seed production, post-harvest handling and storage techniques in cocoa and rubber

24 Clonal multiplication techniques in cashew

25 Criteria for selection of mother tree and seed nut, seed nut and seedling standards and elite seedling production in coconut

26 Criteria for selection of mother tree and seed nut, seed nut and seedling standards and elite seedling production in arecanut

27 Criteria for selection of mother tree and seed nut, seed nut and seedling standards and elite seedling production in oil palm

28 Criteria for selection of mother tree and seed nut, seed nut and seedling standards and elite seedling production in palmyrah

29 Seed production, post-harvest handling and storage methods in aswagantha

30 Seed production, post-harvest handling and storage methods in Thipalli and babchi

31 Seed production, post-harvest handling and storage methods in phyllanthus and kalmegh

32 Seed production, post-harvest handling and storage methods in senna and periwinkle

33 Seed production, post-harvest handling and storage methods in sida and basil

34 Seed production, post-harvest handling and storage methods in Mint

PRACTICAL SCHEDULE

1 Study on the floral biology and pollination mechanism

2 Collection and identification of seeds of fruits, flowers, spices, plantation and medicinal crops

3 Selection of mother plants - phenotypic characters and genotypic characters

4 Selection of seed nuts and planting methods for elite seedling production in coconut, arecanut and palmyrah

5 Practicing germination improvement treatments in fruits and flower crops

6 Practicing seed germination enhancement techniques in spices and plantation crops

7 Practicing seed germination enhancement techniques in medicinal crops

8 Selection of planting materials and sowing methods for vegetative propagules

9 Nursery management practices for elite seedling production

10 Practicing seed extraction methods - wet and dry methods

11 Practicing seed grading, upgrading techniques in fruits, spices, plantation and medicinal crops

12 Standardizing grading and upgrading techniques in flower crops

13 Study of seed storage techniques in papaya, flower, spices and medicinal crops

14 Seed handling and storage techniques of recalcitrant seeds

15 Planning for seed production - economics of seed production in flower crops

16 Visit to mother plant orchard and medicinal garden

17 Final practical examination

SUGGESTED READINGS

1 Hartman, H.T and Kester, D.E. 2000. Plant Propagation: Principles and Practices. Prentice Hall, New Jersey, USA.

2 Singh, S. P. 2001. Seed Production of Commercial Vegetables. Agrotech, New Delhi.

3 Vanangamudi, K. and Natarajan, K. 2008. Advances in Seed Science and Technology. Quality Seed Production in Spices, Plantation, Medicinal and Aromatic crops (Vol. 5). Agrobios. Jodhpur.

4 Vanangamudi, K. M. Prabu, and Lakshmi, S. 2012. Advances in Seed Science and Technology Vol. 7. Flower Seed Production. Agrobios, Jodhpur.

5 Chadha, K.L. 1995. Advances in Horticulture (Volume 1 to 13). Malhothra Publishing House, New Delhi.

6 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4233836/

7 https://www.academia.edu/35629702/Hybrid_Seed_Production_and_Flowers

8 http://www.agrimoon.com/horticulture-icar-ecourse-pdf-books/

9 https://cbp.icar.gov.in/EBook.aspx

SUGGESTED WEBSITES

1 www.cimap.res.in/english/index.php

2 www.dmapr.org.in

3 http://ecoursesonline.iasri.res.in/course/view.php?id=153

4 http://ecoursesonline.iasri.res.in

5 http://www.celkau.in/Crops/Plantation%20Crops/Rubber/production.aspx

6 http://sbc.ucdavis.edu/seed-production

OUTCOME EXPECTED

- Successful completion of this course enables the students to take up elite seed and seedling production on commercial scale.

SST 506 Seed Production Techniques in Forage, Pasture and Green Manure Crops 2 (1+1)

WHY THIS COURSE:

Agriculture and animal husbandry in India is interwoven and livestock is the source of income when crop failed. To feed the livestock population, cultivation and seed production of fodder and forage crops are much important. Likewise green manure crops maintain soil health, which created heavy demand for quality seed. Hence, study of seed production techniques in these crops will help to produce quality seeds to meet the growing needs.

OBJECTIVE

To impart knowledge on basic principles and methods of quality seed production in forage and green manure crops.

THEORY

Unit I :

Scope and importance of seed production in forage, pasture and green manure crops - factors influencing seed production - seasonal influence; problems and constraints in seed production - seed set, shattering and seed dormancy; vegetative and clonal propagules and apomictic seed.

Unit II :

Quality seed production techniques in forage legumes - lucerne, hedge lucerne, Stylosanthus, cowpea berseem and leucaena.

Unit III :

Seed production techniques fodder sorghum, fodder maize and fodder oats; seed and planting material production techniques in forage grasses - bajra napier grass, guinea grass, deenanath grass and Cenchrus sp.

Unit IV :

Seed production techniques in major green manure crops - Glyricidia, Sesbania sp., sunnhemp, and Tephrosia sp.

Unit V :

Post-harvest seed handling - processing, threshing, grading and upgrading; dormancy breaking and germination improvement - quality standards for seed and vegetative propagules.

PRACTICALS

Seed collection and identification - seed setting and shattering loss - seed maturity; physiological and harvestable maturity - seed extraction and threshing - seed viability assessment - seed and clonal standards - seed quality analysis - tiller wise quality analysis in forage and fodder - planting materials preparation and planting methods - ratooning on seed quality - identification of dormancy and breaking methods - vegetative propagules preparation and planting methods - seed grading and upgrading -economics of seed production in fodder, forage and green manure crops – visit to fodder seed production fields.

LECTURE SCHEDULE

1 Scope and importance of seed production in forage, pasture and green manure crops

2 Factors influencing seed production in forage, pasture and green manure crops

3 Problems and constrains in seed production of forage, pasture and green manure crops

4 Vegetative and clonal propagules, types of apomixis in forage and pasture crops

5 Seed production techniques in lucerne and hedge lucerne

6 Seed production techniques in stylosanthus and fodder cowpea

7 Seed production techniques in berseem and leucaena

8 Mid - semester examination

9 Seed production techniques in fodder sorghum

10 Seed production techniques in fodder maize and oats

11 Techniques for seed and planting material production in bajra napier grass, guinea grass, deenanath grass and Cenchrus sp.

12 Techniques for seed and planting material production in Glyricidia and Sesbania sp.

13 Seed production techniques in sunnhemp and Tephrosia sp.

14 Seed processing, threshing, grading and upgrading techniques in forage, pasture and green manure crops

15 Seed dormancy and breaking treatments in forage, pasture and green manure crops

16 Seed germination improvement techniques in forage, pasture and green manure crops

17 Quality standards for seed and vegetative propagules of forage, pasture and green manure crops

PRACTICAL SCHEDULE

1 Collection and identification of fodder, forage and green manure seeds

2 Study on clonal standards and preparation of planting materials in forage and fodder crops

3 Practicing different planting methods in forage and fodder crops

4 Estimation of seed setting and shattering loss in fodder, forage and green manure crops

5 Study on physiological maturity indices in fodder, forage and green manure crops

6 Practicing seed extraction methods in fodder, forage and green manure crops

7 Assessment of seed quality in different tillers in forage and fodder crops

8 Study on effect of ratooning on seed quality in forage and fodder crops

9 Practicing grading and upgrading techniques in forage, fodder and green manure crops

10 Assessment of seed viability in forage and fodder crops

11 Identification of type of dormancy in forage, fodder and green manure crops

12 Practicing different dormancy breaking treatments in forage, fodder and green manure crops

13 Practicing seed quality enhancement techniques in forage and fodder crops

14 Practicing seed quality enhancement techniques in green manure crops

15 Economics of seed production in fodder, forage and green manure crops

16 Visit to forage and fodder seed production farms

17 Final practical examination

SUGGESTED READINGS

1 Farity, D.T and Hampton, J.C. 1997. Forage Seed Production. Vol. I. Temperate Species. CAB International Publications. UK.

2 Froma, J. 1997. Temperate Forage Legumes. CAB International Publications. UK.

3 Gutterridge, R.G. 1997. Forage Tree Legumes in Tropical Agriculture. CAB International Publications, UK.

4 FAO, 2007. Quality Declared Seed System. FAO Plant Production and Protection Publication, FAO, Rome.

5 Masilamani, S. and Sivasubramanian, K. 2016. Green Manure Seed Production. Kalyani Publications, New Delhi.

6 https://www.cabi.org/bookshop/book/9780851992143

7 https://cgspace.cgiar.org/handle/10568/49375

8 http://www.fao.org/docrep/009/a0503e/a0503e00.htm

9 http://www.igfri.res.in/pdf/old_bulletins/tropical_pasture.pdf

10 https://cgspace.cgiar.org/bitstream/handle/10568/4479/Seed.pdf? sequence=1&i Allowed=y

SUGGESTED WEBSITES

1 www.igfri.res.in/

2 https://cgspace.cgiar.org/handle/10568/4479

3 https://www.euroseeds.eu/grasses-and-clovers

4 https://www.sare.org/learning-center/green-manures

5 www.ndri.res.in/ndri/Design/forageres_mag_cen.html

6 http://orgprints.org/30588/1/Sort%20Out%20Your%20Soil.pdf

OUTCOME EXPECTED

- After completion of course the students gain confidence to start a seed venture on forage and green manure crops.

SST 507* Seed Legislation and Certification 3 (2+1)

WHY THIS COURSE:

Awareness on usage of quality seeds among farmers increases the seed demand. To regulate the seed quality and to avoid the spurious seeds in the market, seed legislation and certification procedures should be known by all the stake holders. Hence, this course will provide comprehensive knowledge on seed policies, seed law enforcement and seed certification procedures to the learners.

OBJECTIVE

To impart knowledge on seed legislation in relation to seed certification and quality control systems.

THEORY

Unit I :

Genesis of seed Industry in India; seed quality control - concept and objectives; regulatory mechanisms and statutory bodies- the Seeds Act, 1966 and the Seed Rules, 1968; role and functions of Central Seed Committee and Central Seed Certification Board.

Unit II :

The Seeds (Control) Order, 1983 - New Policy on Seed Development, 1988 - Exim Policies - National Seed Policy, 2002 - Plant Quarantine Order (Regulation of Import into India), 2003 – Plant Quarantine Act

Unit III :

Introduction to WTO and IPR - UPOV and its role in plant variety protection Seed Bill (2004 and 2011) - PPV&FR Act, 2001 and Rules, 2003 - OECD seed certification schemes - seed certification system in SAARC countries, Europe, Canada, Australia and USA.

Unit IV :

Seed certification - history and objectives; seed certification agency - role of certification agency / department and seed certification officers; phases of seed certification; field and seed standards; field inspection - counting procedures - liable for rejection (LFR) - downgrading and partial rejection - reporting.

Unit V :

Post-harvest inspection – construction of seed lot number; seed sampling - testing - labeling, sealing and grant of certificate - types and specifications for tags and labels; seed lot validity and revalidation; stop sale order, penalties, appellate authority; maintenance of records and registers at seed processing units and seed dealers - verification procedures; role of seed analyst and seed inspector in quality regulation.

PRACTICALS

Preparation of sowing reports - varieties transplanted direct sown crops and hybrids Verification of sowing report - seed certification procedure -stages of inspection for varieties hybrids and procedure - double count- procedure to remove partial pollen shedders and shedding tassels -LFR, partial rejection and downgrading-reasonprocedure and preparation of reports.-seed yield estimation single and multiple crops- procedure followed by seed inspector- planting ratio and block method; identificationof genetic and physical contaminants and roguing operations - assessment of field standards for different crops - seed yield estimation; inspection and maintenance of records in processing unit - float test - preparation of processing report and assigning seed lot number – Procedure to issue of tag, specification, bagging, labelling and sealing; visit to seed certification department, grow out test field and seed retail shop - verification of records and reporting.

LECTURE SCHEDULE

1	Genesis of seed industry in India
2	Concept and objectives of seed quality control
3	Salient features of different sections of the Seeds Act, 1966
4	Parts and clauses of the Seed Rules, 1968
5	Role and functions of Central Seed Committee and Central Seed Certification Board
6	The Seeds (Control) Order, 1983 and its significance on seed quality control
7	New Policy on Seed Development, 1988 and its impact on seed industry
8	Exim policies on seed and planting materials
9	Salient features of National Seed Policy, 2002
10	Plant Quarantine (Regulation of import into India) Order, 2003 & Plant Quarantine Act
11	WTO and IPR and their impact on seed trade
12	UPOV and its role on plant variety protection
13	PPV&FR Act, 2001 and PPV&FR Rules, 2003
14	Salient features of Seed Bill, 2004 & 2011
15	OECD seed certification schemes
16	Seed certification system in SAARC countries, Europe, Canada, Australia and USA
17	Mid-semester examination
18	History and concept of seed certification
19	Role and functions of seed certification agency and organizational set up
20	Phases and procedures of seed certification

21 Field and seed standards for agricultural crops

22 Field and seed standards for horticultural crops

23 Certification standards for tissue culture, clonal and vegetative propagules

24 Principles and methods of field inspection, counting procedures and reporting

25 Procedures for issue of liable for rejection (LFR) report, partial rejection and downgrading

26 Post-harvest inspection, processing report, reprocessing and method of assigning seed lot number

27 Seed sampling procedures, sampling intensity, types of samples and despatch to STL

28 Procedure for labeling, sealing and grant of certificate; types and specifications for tags and labels

29 Seed lot validity and revalidation procedures

30 Duties of seed certification officers and seed analysts in seed quality regulation

31 Duties and powers of seed inspectors in seed law enforcement

32 Maintenance of records and registers at processing units, seed dealers and verification procedures

33 Procedure for issue of stop sale order, penalties and appellate authority

PRACTICAL SCHEDULE

1 Preparation of sowing report for varieties and hybrids in transplanted and direct sown crops

2 Yield estimation in single and multiple harvest crops

3 Field inspection - estimation of area and isolation distance, stages of inspection for varieties hybrids and procedure double count

4 Practicing field counting procedures for row planting and broadcasted varieties

5 Practicing field counting procedures for varieties in direct sown and transplanted crops

6 Practicing field counting procedures for hybrids in row planting, block method and double count

7 Identification of genetic and physical contaminants and practicing roguing operations

8 Assessment of field standards for different crops and reporting

9 Visit to seed certification department and grow out test field, procedure followed by seed inspector

10 LFR, partial rejection and downgrading-reason procedure and preparation of reports

11 Practicing post-harvest inspection in pulses and groundnut

12 Visit to seed processing unit and studying the procedures of maintaining registers and records

13 Practicing float test, preparation of processing report and assigning seed lot number

14 Practicing bagging, labelling and sealing of certified seed lots

15 Procedure to remove partial pollen shedders and shedding tassels

16 Visit to seed retail shop and studying the procedures of maintaining registers and records

17 Final practical examination

SUGGESTED READINGS

1 Tunwar, N. S and Singh, S. V. 2003. Indian Minimum Seed Certification Standards. Central Seed Certification Board, Ministry of Agriculture, GOI, New Delhi.

2 Anon, 2016. Manual of Seed Certification Procedures. Directorate of Seed Certification, Coimbatore, Tamil Nadu.

3 Ramamoorthy, K., Sivasubramaniam, K. and Kannan, M. 2006. Seed Legislation in India. Agrobios, Jodhpur, Rajasthan.

4 Mishra, D. K., Khare, D., Bhale, M. S. and Koutu, G. K. 2011. Handbook of Seed Certification. Agrobios, Jodhpur, Rajasthan.

5 Chakrabarthi, S. K. 2010. Seed Production and Quality control. Kalyani Publishers, New Delhi.

6 Renugadevi, J, Srimathi, P., Renganayaki, P. R. and Manonmani, V. 2012. A Handbook of Seed Testing. Agrobios, Jodhpur, Rajasthan.

7 Trivedi, P.C. 2011. Seed Technology and Quality Control. Pointer Publications, Jaipur, Rajasthan.

8 Neema, N.P. 1986. Principles of Seed Certification and Testing. Allied Publishers, New Delhi

9 Sharma, P. 2008. Seed Legislation. Gene-tech Book Publishers, New Delhi.

10 Agarwal, R.L. 2012. Seed Technology. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.

11 http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material /INDIAN_ MINIMUM_SEED_CERTIFICATION_STANDARDS.pdf

12 https://books.google.co.in/books/about/Principles_of_Seed_ Certification_and_Tes.html?id=SQWHAAAACAAJ&redir_esc=y

13 https://dl.sciencesocieties.org/publications/books/tocs/cssaspecialpubl /theroleofseedce

SUGGESTED WEBSITES

1 www.fao.org

2 www.agri.nic.in

3 www.agricoop.nic.in

4 www.gov.mb.ca

5 http:/agritech.tnau.ac.in

5 www.betterseed.org

7 www.oecd.org/india/

8 http://www.tnagrisnet.tn.gov.in/

OUTCOME EXPECTED

- This course will be useful to develop human resource on seed certification and legislation. Successful completion of this course enables students to become a Seed Certification Officer and Seed Inspector.

SST 508* Post Harvest Handling and Storage of Seeds 3 (2+1)

WHY THIS COURSE:

Healthy seeds are the demanding enterprise of the recent era for the production of high yield in the next season. The seeds must be well processed and stored for the maintenance of high-yielding crop. During storage, major losses of seeds are caused by various biotic and abiotic factors. There is a need to apply proper post harvest handling and storage techniques, which ultimately improve the market value and quality of the seed.

OBJECTIVE

To impart knowledge on principles, techniques and methods of seed processing, treatment and storage.

THEORY

Unit I :

Seed processing - objectives and principles; processing sequence - threshing, shelling, ginning, extraction methods; drying - principles and methods; seed cleaning, grading, upgrading - methods - machineries and equipments - scalper, pre-cleaner, cleaner cum grader, specific gravity separator, indented cylinder, disc separator, spiral separator, velvet separator, magnetic separator, needle separator and electronic colour sorter - working principles and functions.

Unit II :

Online seed processing - elevators and conveyers - processing plant - specifications, design and layout; mechanical injury - causes and detection - management.

Unit III :

Seed treatment - methods - pre and mid storage seed treatments, seed treating formulations and equipments; packaging materials - types - bagging and labeling; seed blending - principle and method.

Unit IV :

Seed storage - purpose and importance - factors affecting storage, optimum condition for storage of different seeds; storage principles - Harrington's thumb rule - concepts and significance of moisture equilibrium - maintenance of safe seed moisture - physical, physiological, biochemical and molecular changes during seed storage - storage behaviour of orthodox and recalcitrant seeds - prediction of viability - viability nomograph.

Unit V :

Methods of seed storage - modified atmospheric storage - ultra dry storage - vacuum storage - cryopreservation - germplasm storage - gene banks – IPGRI and NBPGR - International and National seed storage facilities; seed storage godown - structures - maintenance - sanitation.

PRACTICALS

Seed extraction - wet and dry methods - seed drying methods - principle and methods - seed processing sequence for different crops - design of processing plant - equipments - estimation of processing efficiency - practicing seed grading and upgrading techniques - delinting methods - assessment of mechanical damage - visit to seed processing unit - seed packaging - effect of packaging materials on seed longevity - prediction of viability during storage - viability nomograph and accelerated ageing test - assessing physical, physiological and biochemical changes during seed storage - study on storage behaviour of recalcitrant seeds - pre-storage seed treatments - protectants - antioxidants - halogens - practicing seed blending methods – sanitation and fumigation - visit to seed storage godown and cold storage unit.

LECTURE SCHEDULE

1 Objectives and principles of seed processing

2 Sequence of seed processing for different crops

3 Methods of seed threshing, shelling and ginning

4 Seed extraction methods for different crops

5 Principles and methods of seed drying

6 Methods and machineries for seed cleaning, grading and upgrading

7 Working principles and functions of scalper and pre-cleaner

8 Working principles and functions of cleaner cum grader

9 Working principles and functions of specific gravity separator and indented cylinder

10 Working principles and functions of disc separator and spiral separator

11 Working principles and functions of velvet separator and magnetic separator

12 Working principles and functions of needle separator and electronic colour sorter

13 Working principles and functions of elevators and conveyers

14 Specifications, design and layout of processing plant

15 Causes of mechanical injury, detection methods and its management

16 Principles and methods of pre and mid storage seed treatments, seed treating formulations and equipments

17 Mid- semester examination

18 Types of packaging materials, methods of bagging, labeling and stacking

19 Principle and method of seed blending

20 Importance and stages of seed storage

21 Principles of seed storage and Harrington's thumb rule

22 Factors affecting seed storage and optimum condition for storage of different seeds

23 Influence of seed storage containers on seed longevity

24 Concepts and significance of moisture equilibrium in seed storage environment

25 Study on physical and physiological changes during seed storage

26 Study on biochemical and molecular changes during seed storage

27 Study on storage behaviour of recalcitrant seeds

28 Prediction of seed viability and viability nomograph

29 Controlled and modified atmospheric storage, ultra-dry storage and vacuum storage methods

30 Germplasm storage, methods of cold storage and techniques of cryopreservation

31 Guidelines for storage in gene banks, IPGRI and NBPGR

32 International and National seed storage facilities

33 Study on seed storage structures

34 Maintenance of seed storage godown

PRACTICAL SCHEDULE

1 Practicing seed extraction methods for different crops

2 Practicing different seed drying methods

3 Study on seed processing sequence for different crops

4 Estimation of processing efficiency of cleaner cum grader

5 Practicing seed grading and upgrading techniques

6 Practicing delinting in cotton

7 Assessment of mechanical damage in different crops

8 Visit to seed processing unit

9 Effect of packaging materials on seed longevity

10 Prediction of seed longevity using viability nomograph and accelerated ageing test

11 Assessing physical and physiological changes in seeds during storage

12 Assessing biochemical changes in seeds during storage

13 Determination of seed longevity in recalcitrant seeds

14 Studying the effect of different pre-storage seed treatments on seed quality

15 Practicing seed blending technique and germination assessment

16 Visit to seed storage godown and cold storage unit and study sanitation and fumigation methods

17 Final practical examination

SUGGESTED READINGS

1 Barton, L.V. 1961. Seed Preservation and Longevity, (Vol. 1). Leonard Hill, London.

2 Gregg, B.R, Law, A.G, Virdi, S.S and Balis, J.S. 1970. Seed Processing. Avion Printers, New Delhi.

3 Gupta, D. 2009. Seeds: Their Conservation Principles and Practices. Sathish Serial Publishing House. New Delhi.

4 Justice, O.L.and Bass, L.N. 1978. Principles and Practices of Seed Storage.Agriculture Hand Book No. 506, Castle House Publication Ltd., Washington.

5 Kulkarni, G. N. 2011. Principles of Seed Technology. Kalyani Publishers, New Delhi.

6 Maiti, R.K., Sarkar, N.C. and Singh, V.P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.

7 Padmavathi, S., Prakash, M., Ezhil Kumar, S., Sathiyanarayanan, G. and Kamaraj, A. 2012. A Text Book of Seed Science and Technology, New India Publishing Agency, New Delhi.

8 Sen, S. and Ghosh, N. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.

9 Singhal, N. C. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.

10 http://dfsc.dk/pdf/Handbook/chapter8_internet.pdf

11 https://naldc.nal.usda.gov/download/CAT87208646/PDF

12 https://www.springer.com/in/book/9780792373223

13 http://203.64.245.61/fulltext-pdf/EB/1900-2000/eb0021.pdf

14 https://www.kopykitab.com/ebooks/2016/05/6997/sample/sample_6997.pdf

15 https://trove.nla.gov.au/work/6862691?q&sort=holdings+desc&=1541066209257&versionId=45008917+251246346

16 http://www.worldseed.org/wp-content/uploads/ 2017/01/Seed-Production-Good- practice-10.01.17-final.pdf

SUGGESTED WEBSITES

1 http://www.fao.org/3/a-ah803e.pdf

2 agritech.tnau.ac.in/seed_certification/seedtech_index.html

3 http://ecoursesonline.iasri.res.in/mod/page/view.php?id=17806

4 http://www.bcseeds.org/wp-content/uploads/2015/01/Seed-Processing-2015update.pdf

5 https://www.carolinafarmstewards.org/wpcontent/uploads/2012/05/SeedProcessingandStorageVer_1pt3.pdf

OUTCOME EXPECTED

- The students will understand the principles and mechanism involved in seed processing, storage techniques and management practices to arrest the seed deterioration. Students will also acquire skill on seed handling and storage methods on commercial basis.

SST 509* Seed Quality Testing and Enhancement 2 (1+1)

WHY THIS COURSE:

Seed is the basic input in agriculture and the productivity is mainly depends on field population of plants. By sowing quality seeds, population can be maintained. Hence, it is necessary to know the quality parameters to be analyzed. Through seed treatments, the performance of seed can be improved. Especially to address the drought and climate change the knowledge on seed enhancement techniques is much essential.

OBJECTIVE

To impart knowledge on principles, techniques and methods of seed testing and seed quality enhancement.

THEORY

Unit I :

Seed testing - history and development; ISTA and its role in seed testing; seed testing in India- seed lot, types of seed and size, seed sampling - intensity and methods, sampling devices - sub sampling- receipt and registration of submitted sample in the laboratory; purity analysis - components and procedure - determination of other distinguishable varieties (ODV) and test weight determination - heterogeneity test - method of testing coated and pelleted seeds; seed moisture estimation - principles and methods, application of tolerances.

Unit II :

Seed germination test - requirements, media and methods - seedling evaluation and reporting results; viability test (TZ test) - principle, procedure and evaluation; vigour tests - concept of seed vigour and vigour test - types of vigour tests - direct and indirect tests - physical, physiological and biochemical tests - principles and methods; seed health test - principles and methods. Seedling evaluation tolerance and reporting results.

Unit III :

Genetic purity assessment - laboratory methods - physical, chemical, biochemical and molecular tests - growth chamber and field testing (Grow Out Test) methods; testing of GM seeds; advanced non-destructive techniques of seed quality analysis - soft x-ray imaging - hyperspectral imaging, thermal imaging - spectroscopy - e-nose and machine vision techniques; storage of guard sample - referral test; application of tolerance in seed testing.

Unit IV :

Seed quality enhancement techniques history and development- classification - physical, physiological and protective seed treatments - special seed treatments; physical seed treatment - liquid floatation, specific gravity separation, irradiation, electric and electro-magnetic seed treatments - principles and methods - seed pelleting and coating principles, purpose and methods.

Unit V :

Physiological seed enhancement treatments - seed infusion, seed priming - principles and methods - physiological, biochemical and molecular mechanisms; biological seed treatments - integrated seed treatment and concept of designer seed. Pre germination and fluid drilling technique.

PRACTICALS

Sampling and dividing methods - determination of seed test weight and heterogeneity test - physical purity analysis - seed moisture estimation - methods and equipment - seed germination test and seedling evaluation - quick viability (tetrazolium) test and evaluation - vigour tests - genetic purity assessment- seed health tests - physical purity analysis-components procedures and results - direct indirect and special test in laboratory and conventional methods imagine analysis - identify bacteria fungi and insect - seed coating and pelleting use of adhesive and filler materials - Practicing seed infusion and microbial inoculation treatments - designer seed treatment- visit to seed testing laboratory - seed enhancement techniques - physical treatments and water floatation techniques - seed coating and pelleting - seed infusion and seed priming - microbial inoculation - pre-germination technique - integrated seed treatment.

LECTURE SCHEDULE

1	History, concept and role of seed quality testing; ISTA and its role on seed quality seed testing in India
2	Seed lot, sampling intensity and methods of sampling, types of seed and size, seed samples and heterogeneity testing
3	Receipt and registration of submitted sample in the laboratory, Physical purity analysis, determination of other distinguishable varieties (ODV) and test weight determination
4	Principles and methods of seed moisture estimation
5	Procedures and methods of seed germination test; principle and procedure of viability test
6	Concept of seed vigour and vigour tests; principles and methods of physical, physiological and biochemical vigour tests
7	Principles and methods of seed health testing
8	Mid- semester examination
9	Principles and procedures of genetic purity assessment
10	Principles and testing procedures for GM seeds - direct indirect and special test in laboratory and conventional methods imagine analysis
11	Non-destructive techniques of seed quality analysis - soft x-ray, hyper spectral imaging, thermal imaging, spectroscopy, e-nose and machine vision techniques

12 Principles and testing procedures for coated and pelleted; application of tolerance in seed testing; storage of guard sample and referral test

13 Principles and methods of physical seed treatments - specific gravity separation, irradiation, electric and electro-magnetic seed treatments

14 Principles and methods of seed pelleting and coating.

15 Principles and methods of physiological seed treatments - seed infusion and seed priming

16 Practicing seed infusion and microbial inoculation treatments and designer seed treatment

17 Study on concept of protective, biological and integrated seed treatments pre germination and fluid drilling techniques

PRACTICAL SCHEDULE

1 Practicing seed sampling and dividing procedures

2 Determination of seed test weight and assessing sample heterogeneity

3 Conducting physical purity analysis components procedures and reporting results

4 Estimation of seed moisture content

5 Conducting seed germination test and seedling evaluation

6 Conducting quick viability test and evaluation

7 Conducting seed vigour tests

8 Biochemical and molecular methods of genetic purity of assessment

9 Conducting seed health tests

10 Visit to seed testing laboratory

11 Practicing water floatation techniques for seed quality enhancement

12 Practicing seed coating and pelleting methods use of adhesive and filler materials

13 Practicing seed infusion and seed priming techniques

14 Practicing microbial inoculation seed treatments

15 Practicing pre-germination technique

16 Practicing integrated seed treatment in different crops

17 Final practical examination

SUGGESTED READINGS

1 Chakrabarthi, S.K. 2010. Seed Production and Quality Control. Kalyani Publishers. New Delhi.

2 Renugadevi, J., Srimathi, P., Renganayaki, P. R., and Manonmani, V. 2012. A Hand book of Seed Testing. Agrobios. Jodhpur, Rajasthan.

3 Tridevi, P.C. 2011. Seed Technology and Quality Control. Pointer Publication. Jaipur, Rajasthan.

4 Agrawal, P.K. 1993. Hand book of Seed Testing. Ministry of Agriculture, GOI, New Delhi.

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6 Agrawal, P.K. and Dadlani, M. 1992. Techniques in Seed Science and Technology. 2nd Ed. South Asian Publications.

7 ISTA. 1999. Seed Science and Technology, 27th supplement.

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10 International Seed Testing Association. 2018. Handbook on Seedling Evaluation, 4th Edition, Published by ISTA, Zurichstr, Switzerland.

11 International Seed Testing Association. 2019. International Rules for Seed Testing 2019. Published by ISTA, Zurichstr, Switzerland.

12 Copeland, L. O. and McDonald, M. B. 2001. Principles of Seed Science and Technology. 4th Ed. Kluwer Academic publishers, USA.

13 http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material/INDIAN MINIMUM SEED CERTIFICATION STANDARDS.pdf.

14 www.kopykitab.com/Seed-Testing-and-Quality-Control-by-Vasudevan-SN

15 https://www.jstor.org/stable/10.14321/j.ctt7zt51m

16 https://link.springer.com/chapter/10.1007/978-1-4615-1619-4_13

17 https://www.researchgate.net/publication/269694458_QUALITY_ SEED_PRODUCTION_ITS_TESTING_AND_CERTIFICATION_STANDAD

18 https://www.seedtest.org/upload/cms/user/ISTAMethodValidationfor eedTesting-V1.01.pdf

19 https://www.intechopen.com/books/new-challenges-in-seed-biology-basic-and-translational-research-driving-seed-technology/recent-advances-in-seed-enhancements

SUGGESTED WEBSITES

1 http://agritech.tnau.ac.in/seed/Seed_seedtesting.html

2 https://core.ac.uk/download/pdf/85210907.pdf

3 https://www.betterseed.org/resources/seed-testing-accreditation-schemes/

4 http://sbc.ucdavis.edu/About_US/Seed_Biotechnologies/Seed_Enhancement/

5 https://www.seedtest.org/en/international-rules-for-seed-testing-content-1-1083.html

OUTCOME EXPECTED

- Successful completion of this course by the students will be useful to acquire technical skill on seed quality analysis which leads to the development ofhuman resource on seed quality analysis.

SST 510 Seed Technology of Tree Species 2 (1+1)

WHY THIS COURSE:

Tree seed production is an important primary niche for carrying forward sustainable forest resource management. Knowledge of the seed biology of a tree species is essential to successful seed production and handling of tree crops. The life cycle must be known to plan for genetic improvement, production, collection, conditioning, storage and planting of the seeds for propagation of trees.

OBJECTIVE

To make the students gain knowledge on seed production and handling techniques of various tree species.

THEORY

Unit I :

Importance of tree seeds - seed quality in plantation establishment - scope of seed production in tree species; seed structure and its significance in natural regeneration of forest species.

Unit II :

Reproductive biology - angiosperms and gymnosperms - reproductive age - seasonal influence on flowering - reproductive efficiency; factors influencing seed set - pollination - pollinating agents - self incompatibility - seed dispersal - mode andmechanism of dispersal.

Unit III :

Seed stand - selection and delineation - seed production area - seed zone - selection criteria for candidate, plus and elite trees; seed orchards - definition - types - seedling seed orchard and clonal seed orchard; establishment and management of seed orchard - pollen dilution zone; OECD certification programmes for forest reproductive materials and seeds . ISTA certification standards for tree spices

Unit IV :

Physiological maturity - maturity indices - determining optimum harvestable maturity; seed collection - methods - factors influencing seed collection - precautions in collection of recalcitrant seeds; seed extraction - methods - wet, dry and cone extraction; drying - critical moisture content - seed processing; dormancy - types of dormancy in tropical, sub tropical and temperate tree seeds - dormancy breaking treatments; recalcitrant seeds - storage mechanism

Unit V :

Seed production and handling techniques in important tree borne oil seeds (mahua, karanja, neem, simaruba, Callophyllum); timber (teak, sandal, pine, cedar, red sanders, Dalbergia); fuel wood (Acacias); pulp wood (bamboo, Ailanthus, Casuarina, Melia, Eucalyptus); fodder (Leucaena, Albizzia) and ornamental (Cassia, Delonix) tree species.

PRACTICALS

Internal and external tree seed structure - phenology of different tree species -selection procedure of candidate and plus trees - assessment of seed set, physiological and harvestable maturity - natural regeneration in different tree species - seed dispersal methods and dispersal distance in different species -seed collection techniques in important tree species - seed collection - orthodox and recalcitrant seeds - safetymeasures during collection -seed extraction methods - wet and dry extractions - fruits, pods, cones etc., - study on different seed drying methods and precautions - seed grading and upgrading techniques - seed dormancy breaking methods - germination improvement treatments for elite seedling production - storage of recalcitrant seed - estimation of critical moisture content for safe storage - visit to seed production area and seed orchard - visit to seed processing unit.

LECTURE SCHEDULE

1	Importance of tree seeds, influence of seed quality in plantation establishment and its scope
2	Significance of seed structure in natural regeneration of forest species
3	Reproductive biology of angiosperms and gymnosperms, reproductive age, seasonal influence on flowering and reproductive efficiency
4	Influence of pollination, pollinating agents and self-incompatibility on seed set
5	Seed dispersal mechanism in tree species
6	Selection criteria for candidate, plus and elite tree; selection and delineation of seed production area and seed zone
7	Seed orchards - definition and types, establishment and management of seedling seed orchard and clonal seed orchard and pollen dilution zone
8	Mid -semester examination
9	OECD certification programme for tree seeds ISTA certification standards for tree spices
10	Study on physiological maturity indices for different tree species
11	Methods of seed collection and factors influencing seed collection; precautions in collection of recalcitrant seeds and storage mechanism

12 Seed extraction methods, principles of seed drying and processing

13 Dormancy - types and dormancy breaking methods in different tree species

14 Principles and methods of recalcitrant seed storage

15 Seed production, post harvest handling and storage techniques in mahua, karanja, neem, simaruba, Indian laurel

16 Seed production, post harvest handling and storage techniques in teak, sandal, pine, cedar, red sanders, shisam and acacia

17 Seed production, post harvest handling and storage techniques in bamboo, tree of heaven, casuarina, melia, eucalyptus, leucaena, albizzia, cassia and mayflower

PRACTICAL SCHEDULE

1 Study of internal and external seed structure

2 Study on phenology of different tree species

3 Selection procedures of candidate, plus and elite trees

4 Assessment of physiological maturity indices

5 Assessing natural regeneration in different tree species

6 Study on seed dispersal methods in different tree species

7 Seed collection methods and its influence on seed quality

8 Practicing seed extraction methods for different tree species

9 Practicing seed drying methods for different tree species

10 Practicing seed grading and upgrading techniques in tree crops

11 Practicing seed dormancy breaking methods in tree seeds

12 Practicing seed germination improvement treatments for elite seedling production

13 Estimation of critical moisture content for safe storage of recalcitrant seeds

14 Study on storage methods on longevity of recalcitrant seeds

15 Visit to seed production area and seed orchard

16 Visit to tree seed processing unit and tree seed laboratory at IFGTB

17 Final practical examination

SUGGESTED READINGS

1 Vanangamudi, K., Natarajan, K., Saravanan, J., Natarajan, N., Umarani, R., Bharathi, A. and Srimathi, P. 2007. Advances in Seed Science and Technology: Forest Tree Seed Production (Vol. 4). Agrobios, Jodhpur

2 Sivasubramaniam, K., Raja, K. and Geetha, R. 2012. Recalcitrant Seeds - Causes and Effects. Sathish Serial Publishing House. Azadpur, New Delhi.

3 Dennis, A.J., Schepp, E. N., Green, R. J. and West cott, D. A. 2007. Seed Dispersal. Agrobios, Jodhpur.

4 Ram Prasad and Khandya, A.K. 1992. Handling of Forestry Seeds in India. Associated Publishers, New Delhi.

5 Lars Schmidt, 2000. Guide to Handling of Tropical and Sub Tropical Forest Seed. Danida Forest Seed Centre, Denmark.

6 Khanna, L.S. 1993. Principles and Practices of Silviculture. Khanna Bandhu, Dehradun, India.

7 Zoebel, B and Talbert, T.T.1984. Applied forest tree improvement. Joh willey and Sons, New York.

8 Willan, R.L. 1985. A guide to Forest Seed Handling. FAO, Rome.

9 Negi, S.S. 1998. Forest Tree Seed. International Book Distributors, Dehradun, India.

10 Umarani, R. and Vanangamudi, K. 2004. An Introduction to Tree Seed Technology. International Book Distributors, Dehradun.

11 http://www.fao.org/3/a-ah803e.pdf

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13 https://www.springer.com/gp/book/9783540490289

14 http://www.fao.org/docrep/006/ad232e/ad232e00.htm

15 http://envis.nic.in/ifgtb/pdfs/Tree%20Seed%20Management.pdf

16 https://www.forestry.gov.uk/PDF/FCBU054.pdf/$FILE/FCBU054.pdf

17 https://www.forestry.gov.uk/PDF/FCBU059.pdf/$FILE/FCBU059.pdf

SUGGESTED WEBSITES

1 www.ista.org.in

2 ifgtb.icfre.org/index.php

3 http://www.kfri.res.in/research.asp

4 http://www.fao.org/3/ad232e/AD232E21.htm

5 https://www.srs.fs.usda.gov/pubs/gtr/gtr_so107.pdf

6 http://www.sfri.nic.in/pdf_files/Seed%20Technology.pdf

OUTCOME EXPECTED

- Knowledge of the seed biology of a tree species enable to produce good quality seeds, handling and prevent loss of seeds. The knowledge on sexual life cycle enables them to plan for genetic improvement, production, collection, conditioning, storage, and planting of the seeds.

SST 511 Seed Industry and Marketing Management 2 (1+1)

WHY THIS COURSE:

India has a vibrant seed market. Over the years, the seed industry has evolved side by side with Indian agriculture. Indian seed industry is one of the largest seed market in the world. This course will provide insights in seed industry development, management and seed marketing.

OBJECTIVE

To empower the students to become seed entrepreneurs by imparting knowledge on seed industry management and marketing strategies.

THEORY

Unit I :

Introduction to seed industry - genesis, growth and structure of seed industry - mission and objectives - present status of Indian and global seed industry - role of seed industry in Indian agriculture; government initiatives - seed hubs, seed villages and community seed production system.

Unit II :

Seed industry - organization set up and functions - public, private, MNC's, seed corporations; structure of small, medium, and large scale seed industries, components of seed industry - infrastructure - processing unit - storage godown; public-private partnership - custom seed production - risk management - human resource.

Unit III :

Seed production and distribution systems in state and central government; seed supply chain systems - planning, organization and coordination, staffing, assembling of resources; cost of seed production and distribution - overhead charges.

Unit IV :

Seed marketing - definition - importance - role of marketing; type of markets - domestic and global market - problems and perspectives; marketing policies - seed marketing schemes - marketing channels, responsibilities of dealers - marketing mix.

Unit V :

Seed demand forecasting - purpose - methods and techniques; indenting and seed dispatch procedures and forms - seed store records - maintenance - missing link in seed supply chain; market intelligence - SWOT analysis; seed cost analysis; seed pricing - policy - components of seed pricing - factors - local market rate (LMR) - fixation of procurement and sale price of seed.

PRACTICALS

Status of Indian and global seed industry - assessment of seed demand and supply - planning for establishment of small, medium and large scale seed industry - planning for seed production and establishment of processing unit - economics of seed production in varieties and hybrids-seed pricing and cost analysis - fixation of seed procurement and sale price - domestic marketing channels - risk management - interaction with seed dealers and distributors - visit to National Seed Corporations - visit to MNCs and expert discussion - case studies and SWOT analysis - visit to modern seed processing unit - custom seed production, contract farming and procurement - procedures, planning and preparation of project proposal to setup a seed industry. Data collection on Status of Indian and global seed industry - assessment of factor influencing farmer preference and assessment of seed demand and supply - studyof marketing channels- domestic and international - Maintenance of carry over seeds- assessing risk factors in seeds industries and thier management. Survey and interaction with seed dealer and distributor's.

LECTURE SCHEDULE

1	Introduction, genesis, growth and structure of seed industry
2	Mission, objectives and status of Indian and global seed industry
3	Role of seed industry in Indian agriculture, government initiatives and seed programmes - seed hubs, seed villages and community seed production
4	Organizational set up and functions of seed industry
5	Role of public, private, MNC’s and seed corporations
6	Structure of small, medium and large scale seed industries
7	Components of seed industry and infrastructure - processing unit and storage godown
8	Mid - semester examination
9	Public-private partnership and custom seed production, human resource and risk management
10	Seed production and distribution systems in public sector and seed supply chain system
11	Planning, organization and coordination of seed programme
12	Seed marketing - definition, importance, types, problems and perspectives
13	Seed marketing policies, schemes, responsibilities of dealers and marketing mix
14	Seed demand forecasting - purpose, methods and techniques
15	Seed indenting, despatch procedures and missing link in seed supply chain
16	Market intelligence, SWOT and seed cost analysis
17	Seed pricing policy - LMR and fixation of procurement and sale price

PRACTICAL SCHEDULE

1	Study on Data collection on Status of Indian and global seed industry

2 Assessment of factor influencing farmer preference and assessment of seed demand and forecasting

3 Planning for establishment of small, medium and large-scale seed industry

4 Planning for seed production and establishment of processing unit

5 Economics of seed production in varieties and hybrids

6 Fixation of seed procurement and sale price for varieties

7 Fixation of seed procurement and sale price for hybrids

8 Study of domestic and international marketing channels

9 Maintenance of carry over seeds- assessing risk factors in seeds industries and their management

10 Survey and interaction with seed dealers and distributors

11 Visit to National Seed Corporation

12 Visit to MNCs and expert discussion

13 Case studies and SWOT analysis

14 Visit to modern seed processing unit and advanced seed storage complex

15 Procedures for contractual seed production

16 Preparation of project proposal to setup a seed industry

17 Final practical examination

SUGGESTED READINGS

1 Gurdev Singh and Asokan, S.R. 1991. Seed Industry in India: A Management Perspective Oxford & IBH Publishing Co Pvt. Ltd., New Delhi.

2 Dadheech, P.K. 1996. Seed Programming, Management System and Concepts. Lok Sahitna Kendra, Jodhpur.

3 Acharya, S.S. and Agarwal, N. L. 2004. Agricultural Marketing in India. 4th Ed. Oxford and IBH.

4 Broadway, A. C and Broadway, A. 2003. A Text Book of Agri-business Management.

5 Singh, S. 2004. Rural Marketing - Focus on agricultural Inputs. Vikas Publishing House.

6 Kalyani Singh, A. K. and Pandey, S. 2005. Rural Marketing. New Age Publications.

7 Kugbei, S. 2008. Seed Economics. Scientific Publishers, Jodhpur, Rajasthan.

8 Sharma, P. 2008. Marketing of Seeds, Green-Tech Book Publishers, New Delhi.

9 https://link.springer.com/chapter/10.1007/978-1-4615-1783-2-15

10 http://www.fao.org/3/V4450E/V4450E00.htm

11 https://books.google.co.in/books?id=vPVlBos4WkYC

12 http://download.nos.org/srsec319new/319EL19.pdf

13 https://isengewant.de/Marketing-of-Seeds-By-Premjit-Sharma.pdf

14 https://www.kopykitab.com/A-Handbook-of-Seed-Processing-and-Marketing-by- Gaur-SC

SUGGESTED WEBSITES

1 www.gov.mb.ca

2 www.agricoop.nic.in

3 www.agri.nic.in

4 https://sathguru.com/seed/

5 http://www.fao.org/3/V4450E/V4450E03.htm

6 https://www.seednet.gov.in/smis/SMIS-User%20Manual.pdf

7 https://www.icrisat.org/seed-systems-models-lessons-learned/

8 https://www.bookdepository.com/Seed-Industry-India-Gurdev-Singh/

OUTCOME EXPECTED

- On completion of this course students will gain knowledge and confidence to manage seed industry and able to address the problems in seed industry and seed marketing.

SST 512 Seed Health Testing and Management 2 (1+1)

WHY THIS COURSE:

Seeds are the foundation for crop production and seed health is related to food production in many ways. Healthy seeds, free from insects and seed transmitted pathogens, are a prerequisite for sustainable food production. Seeds are routinely tested to prevent and control plant pests and pathogens that may affect seed quality, seed movement when introduced into new territories. A seed health test is also frequently a phyto-sanitary requirement imposed by national plant protection authorities. This course aids in timely detection and management of seed borne pest and diseases and supply of pest and disease free seeds in market.

OBJECTIVE

To acquaint the students with principle and practices of seed health testing and management of seed borne pathogens and storage insects.

THEORY

Unit I :

History and economic importance of seed health in seed industry and plant quarantine - important seed borne and seed transmitted pathogens - role of microorganisms in seed quality deterioration; storage and field fungi - effect of storage fungi on seeds - Factors influencing storage fungi and management

Unit II :

Transmission of pathogens - mode and mechanism; mycotoxins - types and their impact on plant, animal and human health; seed health testing methods - direct examination, incubation, serological and molecular methods.

Unit III :

Seed certification standards - production of disease free seeds in agricultural and horticultural crops - management of seed borne pathogens; plant quarantine – Indian and international system, post-entry quarantine - Pest Risk Analysis (PRA); sanitaryand phytosanitary system (SPS) - certificates; International seed health initiative (ISHI)on seed health standards.

Unit IV :

Storage pests - insects, mites, rodents and their bionomics - economic importance; insect infestation - sources, kinds and factors influencing, biochemical changes instored seeds due to insect infestation; detection methods and estimation of storage losses; types of seed storage structures - domestic and commercial.

Unit V :

Fumigation - principles and techniques - types of fumigants; seed preservatives and protectants on seed quality - non-chemical methods of management of storage pests - controlled and modified atmospheric storage - trapping devices - IPM for seed storage.

PRACTICALS

Detection of seed borne pathogens - direct examination; incubation methods; serological and molecular methods; seed transmission of seed borne fungi, bacteria and viruses; identification of storage fungi; management of seed borne pathogens - seed treatment methods; visit to seed production fields; identification of storage insects - internal and external feeders; the effect of pre harvest spray on field carryover storage pests; estimation of storage losses due to pests; methods of detection of insect infestation; management of storage pests - pesticides, dose determination, preparation of solution and application; management of storage pests - non-chemical management methods; demonstration of controlled atmospheric storage; safe handling and use of fumigants and insecticides; visit to seed storage godowns.

LECTURE SCHEDULE

1 History and economic importance of seed pathology in seed industry and plant quarantine

2 Important seed borne and seed transmitted pathogens- role of microorganisms in seed quality deterioration

3 Storage and field fungi - effects of storage fungi on seed quality - factors influencing storage fungi and management

4 Transmission of seed borne pathogens - mode and mechanisms

5 Mycotoxins - types and its impact on plant, animal and human health

6 Seed health testing methods - direct examination, incubation method, serological and molecular methods

7 Seed certification standards - production of disease free seeds in agricultural and horticultural crops

8 Mid - semester examination

9 Integrated management of seed borne diseases

10 Plant quarantine - Indian and international systems, post entry quarantine - pest risk analysis - Sanitary and Phytosanitary System (SPS) - certificates; International Seed Health Initiative (ISHI) on seed health standards

11 Storage insects, mites and rodents infesting seeds, their development and economic importance

12 Factors affecting insect infestation and biochemical changes in stored seeds due to insect infestation

13 Sources and kinds of infestation, detection of insect infestation in stored seeds and estimation of storage losses

14 Types of seed storage structures - domestic and commercial

15 Fumigants and fumigation - principles and techniques, preservatives and seed protectants on seed quality

16 Non-chemical methods for managing insect pests of stored seeds

17 Insect trapping devices used in seed storage and IPM for seed storage

PRACTICAL SCHEDULE

1 Detection of seed borne pathogens - direct examination - dry seed examination, seed washing test

2 Detection of seed borne pathogens - Incubation methods - Blotter, 2,4 - D blotter, deep freeze, agar plate methods

3 Detection of seed borne pathogens - Serological methods - ELISA and DIBA

4 Detection of seed borne pathogens - molecular methods - PCR methods

5 Test tube agar method and grow out test to study the transmission of seed borne fungi, bacteria and viruses

6 Detection and identification of storage fungi

7 Management of seed borne pathogens - practicing seed treatment methods

8 Visit to seed production fields

9 Identification of storage insects - internal and external feeders

10 Estimation of storage losses due to pests

11 Physical and chemical methods of detection of insect infestation in stored seeds

12 Pesticides, its dose determination, preparation of solution and its application

13 Management of storage pests - non - chemical methods

14 Study of controlled atmospheric storage

15 Practicing fumigation and safe handling of insecticides and fumigants

16 Visit to seed storage godowns

17 Final practical examination

SUGGESTED READINGS

1 Agarwal, V. K. and Sinclair, J.B. 1996. Principles of Seed Pathology. Edition, CRC Press Inc. Boca Raton, FL.

2 Neergaard, P. 1979. Seed Pathology. Vol. 1. The Macmillan Press Ltd.

3 Karuna, V. 2009. Fundamentals of Seed Pathology. Kalyani Publishers, New Delhi.

4 Karuna, V. 2007. Seed Health Testing. Kalyani Publishers, New Delhi.

5 Cotton, R. T. 2007. Insect Pests of Stored grain and Grain products. Burgess Publ. Co., Minneopolis, Minn., USA

6 Ranjeet, K. 2017. Insect Pests of Stored grain - Biology, Behaviour and Management Strategies. Apple Academic Press, New York, USA.

7 Athanassiou, C.G. and Arthur, F.H. 2018. Recent advances in stored product protection. Springer-Verlag, Germany

8 https://link.springer.com/book/10.1007/978-1-349-02842-9

9 https://www.crcpress.com/Principles-of-Seed-Pathology/Agarwal-Sinclair/p/book/ 97804291 52856

10 https://books.google.co.in/books/about/Seed_Pathology.html?id=lv VJAAAAYAAJ&redir_esc=y

11 https://www.taylorfrancis.com/books/9781315365695

12 https://www.ebooks.com/en-us/610606/insects-of-stored-products/david-rees/

13 https://www.elsevier.com/books/insects-and-seed-collection-storage-testing-and-certification/ kozlowski/978-0-12-395605-7

SUGGESTED WEBSITES

1 www.tnagrisnet.tn.gov.in/

2 www.storedgrain.com.au/

3 https://openlibrary.org/subjects/seed_pathology

4 http://ciat-library.ciat.cgiar.org/articulos_ciat/2015/12620.pdf

5 www.grainscanada.gc.ca/en/

6 https://entomology.ca.uky.edu/ef145

7 http://www.fao.org/3/t1838e/T1838E00.htm#Contents

8 https://www.agric.wa.gov.au/pest-insects/insect-pests-stored-grain

OUTCOME EXPECTED

- Successful completion of this course will provide knowledge on production of healthy seeds by timely detection and management of seed borne pathogens and storage pests to meet phyto-sanitary requirements.

AGRICULTURAL ENTOMOLOGY

Course Title with Credit Load for M.Sc. in Agricultural Entomology

Course code	Course title	Credit Hours
ENT 501*	Insect Morphology	3 (2+1)
ENT 502*	Insect Anatomy and Physiology	3 (2+1)
ENT 503*	Insect Taxonomy	3 (1+2)
ENT 504	Insect Ecology	3 (2+1)
ENT 505*	Biological Control of Insect Pests and Weeds	3 (2+1)
ENT 506*	Toxicology of Insecticides	3 (2+1)
ENT 507	Host Plant Resistance	2 (1+1)
ENT 508	Concepts of Integrated Pest Management	2 (2+0)
ENT 509	Pests of Field Crops	3 (2+1)
ENT 510*	Pests of Horticultural and Plantation Crops	3 (2+1)
ENT 511	Post Harvest Entomology	2 (1+1)
ENT 512	Insect Vectors of Plant Pathogens	2 (1+1)
ENT 513	Principles of Acarology	2 (1+1)
ENT 514	Vertebrate Pest Management	2 (1+1)
ENT 515	Techniques in Plant Protection	1 (0+1)
ENT 516	Apiculture	3 (2+1)
ENT 517	Sericulture	3 (2+1)
ENT 518	Lac Culture	3 (2+1)
ENT 519	Molecular Approaches in Entomology	3 (2+1)
ENT 520	Plant Quarantine, Biosafety and Biosecurity	2 (2+0)
ENT 521	Edible and Therapeutic Insects	2 (1+1)
ENT 522	Medical and Veterinary Entomology	2 (1+1)
ENT 523	Forest Entomology	2 (1+1)
ENT 591	Master’s Seminar	1 (0+1)
ENT 599	Master’s Research	30 (0+30)

*Compulsory Major Courses

I.	**Course title**	**:**	**Insect Morphology**
II.	**Course code**	**:**	**ENT 501**
III.	**Credit hours**	**:**	**3 (2 + 1)**
IV.	**Aim of the course**	**:**	**To acquaint the students with the external morphology of the insect's body and the functioning of various body parts.**

Theory

Unit I

External Morphology: Insect body wall structure, cuticular outgrowths, colouration and special integumentary structures in insects, body tagmata, sclerites and segmentation.

Head- Origin, **s**tructure and modification; mouthparts, antennae, their types and functioning; tentorium and neck sclerites.

Thorax- Areas and sutures of tergum, sternum and pleuron, pterothorax; wings: structure and modifications, venation, wing coupling apparatus and mechanism offlight; legs: structure and modifications.

Abdomen- Segmentation and appendages; genitalia and their modifications; embryonic and post-embryonic development.

Unit II

Insect sense organs (mechano-, photo- and chemo- receptors); Stridulatory organs. Insect defense; Chaetotaxy.

Unit III

Types of immature stages in insect orders, morphology of egg, nymph/larva and pupa. Comparative study of life history strategies in hemi-metabola and holometabola, immature stages as ecological and evolutionary adaptations.

Practical

Examination, study and illustration of the structure of head (including sclerites and sutures, tentorium); morphology of insect thorax in grasshopper, cockroach and beetles (including tergites, pleuron-episternum, epimeron, sternum-presternum, basisternum, sternellum, endoskeleton of thorax-furca, sternal apophyses, pleural apophyses; articulation of wing- wing sclerites; wing venation; study of insect leg, articulation of leg, study of parts of leg including pretarsus. Abdomen – abdominal appendages, pregenital and genital; Study of stridulatory structures and auditory organs. Types of immature stages in insects; their collection and preservation. Identification of immature insects to orders and families, in endopterygote orders, *viz*., Diptera, Lepidoptera, Hymenoptera and Coleoptera.

Learning outcome

Students are expected to have a complete understanding of the comparative morphology of the external features of insects that can be utilized in taxonomy, ecologyand applied entomology.

Suggested Reading

- Chapman RF. 1998. *The Insects: Structure and Function*. Cambridge Univ. Press, Cambridge.
- Chu HF. 1992. *How to Know Immature Insects*. William Brown Publication, Iowa.
- Duntson PA. 2004. *The Insects: Structure, Function and Biodiversity*. Kalyani Publishers, New Delhi.
- Evans JW. 2004. *Outlines of Agricultural Entomology*. Asiatic Publ., New Delhi.
- Gillott C. 1995. *Entomology*, 2nd Ed. Plenum Press, New York, London.
- Gullan PJ and Cranston PS. 2000. *The Insects, An Outline of Entomology*, 2nd Ed. Blackwell Science, UK.
- Peterson A. 1962. *Larvae of Insects*. Ohio University Press, Ohio.
- Richards OW and Davies RG. 1977. *Imm's General Text Book of Entomology*. 10th Ed. Chapman and Hall, London.
- Snodgross RE. 1993. *Principles of Insect Morphology.* Cornell Univ. Press, Ithaca.
- Tembhore DB. 2000. *Modern Entomology*, Himalaya Publishing House, Mumbai.
- Stehr FW. 1998. *Immature Insects*. Vol.I, II. Kendall Hunt Publication, Iowa.

I.	Course title	:	**Insect Anatomy and Physiology**
II.	Course code	:	**ENT 502**
III.	Credit hours	:	**3 (2+1)**
IV.	Aim of the course	:	To impart knowledge about the anatomy and physiology of insect body systems; nutritional physiology; and their applications in entomology.

Theory

Unit I

Scope and importance of insect physiology; physiology of integument, moulting, chemistry of cuticle, biosynthesis of chitin; growth, hormonal control, metamorphosis and diapause; pheromone- secretion, transmission, perception and reception.

Unit II

Physiology and mechanism of digestion, circulation, respiration, excretion, reproduction, secretion (exocrine and endocrine glands) and nerve impulse transmission in insects.

Unit III

Importance of insect nutrition- role of vitamins, proteins, aminoacids, carbohydrates, lipids, minerals and other food constituents; extra and intra cellular microorganisms and their role in physiology; artificial diets.

Practical

Dissection of different insects to study comparative anatomical details of different systems. Latest analytical techniques for analysis of free amino acids of haemolymph; Determination of chitin in insect cuticle; Examination and count of insect haemocytes; preparation and evaluation of various diets; Consumption, utilization and digestion of natural and artificial diets.

Learning outcome

Students are expected to have a thorough understanding of insect growth and development, physiology of exoskeleton, endoskeleton and different organ systems; action and role of hormones, pheromones, physiology of nutrition and its application.

Suggested Reading

- Chapman RF. 1998. *Insects: Structure and Function*. ELBS Ed., London.
- Chapman RF. 2012. The Insects: Structure and Function (Fifth Edition). Cambridge University Press, Cambridge
- Duntson PA. 2004. *The Insects: Structure, Function and Biodiversity*. Kalyani Publishers, New Delhi.
- Gullan PJ and Cranston PS. 2000.*The Insects*: *An Outline of Entomology*, 2nd Ed. Blackwell Science, UK.
- Iatrou K and Gill SS. 2004. Comprehensive Molecular Insect Science (Vol. 1 to 5). Pergamon, Oxford.
- Kerkut GA and Gilbert LI. 1985. *Comprehensive Insect Physiology, Biochemistry and Pharmacology*.Vol. I-XIII. Pergamon Press, New York.
- Klowden MJ. 2013. Physiological Systems in Insects. Academic Press, Amsterdam
- Nation JL. 2008. Insect Physiology and Biochemistry. CRC Press, Boca Raton
- Patnaik BD. 2002. *Physiology of Insects*. Dominant Publishers, New Delhi.

- Richards OW and Davies RG. 1977. *Imm's General Text Book of Entomology.* 10th Ed. Vol.1. *Structure, Physiology and Development*. Chapman and Hall, New York.
- Simpson SJ. 2007. *Advances in Insect Physiology,* Vol. 33, Academic Press (Elsevier), London, UK.
- Wigglesworth VB. 1984. *Insect Physiology.* 8th Ed. Chapman and Hall, New York.

I.	Course title	:	**Insect Taxonomy**
II.	Course code	:	**ENT 503**
III.	Credit hours	:	**3 (1 +2)**
IV.	Aim of the course	:	To sensitize the students on the theory and practice of classifying organisms (with special reference to animals) and the rules governing the same. To introduce the students to the classification of insects up to the level of families with hands-on experience in identifying the families of insects with an emphasis on the practical aspects.

Theory

Unit I

Importance of systematics. Principles of biological classification. Schools of systematics. Species concepts and speciation. International Code of Zoological Classification – criteria of availability, family, genus and species group names – formation, how to write a scientific name, type concept, types in the speciescategory, synonymy, homonymy. History of insect classification; Brief evolutionary history of insects- introduction to phylogeny of Super class Hexapoda,Ellipura (Collembola, Protura). Entognatha (Collembola, Protura, Diplura) andInsecta (Archaeognatha, Zygentoma, Insecta), Molecular systematics, DNA barcoding, karyological and biochemical approaches in taxonomy.

Unit II

Distinguishing characters, general biology, habits and habitats of insect orders and economically important families contained in them. Collembola, Protura, Diplura. Class Insecta: Subclass Apterygota–Archaeognatha, Thysanura. Subclass:Pterygota, Division Palaeoptera–Odonata and Ephemeroptera. Division: Neoptera: Subdivision Polyneoptera: Orthopteroid and Blattoid Orders (Oligoneoptera: Plecoptera, Blattodea, Isoptera, Mantodea, Grylloblattodea (including Mantophasmatodea), Dermaptera, Orthoptera, Phasmatodea, Embioptera, Zoraptera), Subdivision: Condylognatha (Hemipteroid Orders): Thysanoptera, Hemiptera (Sternorrhyncha, Heteroptera, Coleorrhyncha, Auchenorrhyncha); Psocodea (including Pthiraptera, Mallophaga and Siphunculata).

Unit III

Distinguishing characters, general biology, habits and habitats of insect orders and economically important families contained in them (Continued). Division Holometabola (Hymenoptera, Raphidioptera, Megaloptera, Neuroptera, Strepsiptera, Coleoptera, Trichoptera, Lepidoptera, Sinphonaptera, Mecoptera, Diptera.

Practical

Study of Orders of insects and their identification using taxonomic keys; Keying out families of insects of different major Orders: Odonata, Orthoptera, Blattodea (including Isoptera), Mantodea, Hemiptera, Thysanoptera, Psocodea (including Phthiraptera), Neuroptera, Coleoptera, Diptera, Lepidoptera and Hymenoptera; Field visits to collect insects of different orders.

Learning outcome

Students are expected to know the evolution of arthropods, especially insects and other hexapods, and their hierarchical classification. Acquire working skills for collecting, mounting, and preserving insects. Understand the basic concepts of taxonomic hierarchy, identification, taxonomic characters, variations, taxonomic keys and preparation of taxonomic papers. Identify insects of economic importance up to family levels, taking up the insect orders of agriculture and veterinary importance

Suggested Reading

- CSIRO 1990. *The Insects of Australia: A Text Book for Students and Researchers*. 2nd Ed. Vol.I and II, CSIRO. Cornell Univ. Press, Ithaca.
- Freeman S and Herron JC. 1998. *Evolutionary Analysis*. Prentice Hall, New Delhi.
- Gullan PJ and Cranston PS. 2014. *The Insects: An outline of Entomology*. 5th Ed. Wiley-Blackwell Publications, West Sussex, UK.
- Mayr E. and Ashlock 1991. *Principles of Systematic Zoology*.2nd Edition McGraw Hill, New York.
- Richards OW and Davies RG. 1977. *Imm's General Text Book of Entomology.* 10th Ed. Chapman and Hall, London.
- Ross HH.1974. *Biological Systematics.* Addison Wesley Publ. Company.
- Triplehorn CA and Johnson NF. 1998. *Borror and DeLong's Introduction to the Study of Insects.*7th Ed. Thomson/ Brooks/ Cole, USA/ Australia.

I. **Course Title : Insect Ecology**

II. **Course Code : ENT 504**

III. **Credit Hours : 3 (2+1)**

IV. **Aim of the course**

To teach the concepts of ecology, basic principles of distribution and abundance of organisms and their causes. Study life tables, constructing life tables, organization of communities, diversity indices. Train students in sampling methodology, calculation of diversity indices, relating insect population fluctuations to biotic and/ or abiotic causes.

Theory

Unit I

History and definition. Basic Concepts. Organisation of the Biological world. Plato's Natural Balance *vs* Ecological Dynamics as the modern view. Abundance and diversity of insects. Estimates and Causal factors. Study of abundance and distribution and relation between the two. Basic principles of abiotic factors and their generalised action on insects. Implications for abundance and distribution oforganisms including insects- Law of the Minimum, Law of Tolerance and biocoenosis. Systems approach to ecology.

Unit II

Basic concepts of abundance- Model *vs* Real world. Population growth basic models – Exponential *vs* Logistic models. Discrete *vs* Continuous growth models. Concepts of Carrying capacity. Environmental Resistance, Biotic potential of insects and Optimal yield. Vital Statistics- Life tables and their application to insect biology. Survivorship curves. Case studies of insect life tables. Population dynamics- Factors affecting abundance- Environmental factors, dispersal and migration. Seasonality in insects. Classification and mechanisms of achieving different seasonality- Diapause (Quiescence) – aestivation, hibernation.

Unit III

Biotic factors- Food as a limiting factor for distribution and abundance, Nutritional Ecology. Food chain- web and ecological succession. Interspecific interactions- Basic factors governing the interspecific interactions- Classification of interspecific interactions – intraspecific interactions The argument of cost-benefit ratios. Competition- Lotka-Volterra model, Concept of niche ecological homologues, competitive exclusion. Evolution of mimicry, colouration, concept of predator satiation;evolution of life history strategies.

Unit IV

Community ecology- Concept of guild, Organisation of communities- Hutchinson Ratio, May's *d/w*, Relation between the two and their association with Dyar's Lawand Przibram's law. Relative distribution of organisms, Concept of diversity- the Wallacian view. Assessment of diversity. Diversity- stability debate, relevance to pest management. Pest management as applied ecology. Climate change and insect pest/ natural enemy population; ecological engineering.

Practical

Types of distributions of organisms; Methods of sampling insects, estimation of densities of insects and understanding the distribution parameters-Measures of central tendencies, Poisson Distribution, Negative Binomial Distribution; Determination of optimal sample size. Learning to fit basic population growth models and testing the goodness of it; Fitting Holling's Discequation; Assessment of prey-predator densities from natural systems and understanding the correlation between the two; Assessing and describing niche of some insects of a single guild; Calculation of niche breadth, activity breadth and diagrammatic representation of niches of organisms; Calculation of diversity indices- Shannon's, Simpson's and Avalanche Index and understanding their associations and parameters that affect their values; Problem solving in ecology. Field visits to understand different ecosystems and to study insect occurrence in these systems.

Learning outcome

The students are expected to be well versed with the basic concepts of ecology, ecological succession, population ecology, community ecology, nutritional ecology and different insect-ecosysteminteractions

Quantification of insect diversity and abundance, life table analyses, predator- prey and host-parasitoid relations, functional and numerical responses, niche breadth and overlap

Suggested Reading

- Begon M, Townsend CR and Harper JL. 2006. *Ecology: From Individuals to Ecosystems*. 4th Ed.Blackwell Publishing, USA/ UK/ Australia.
- Chapman JL and Reiss MJ. 2006. *Ecology: Principles and Applications*. 2nd Ed.Cambridge Univ. Press, Cambridge.
- Fowler J, Cohen L and Jarvis P. 1998.Practical Statistics for Field Biology. 2nd Ed. John Wiley & Sons, Chichester, West Sussex PO19 8SQ,England.
- Gotelli NJ and Ellison AM. 2004. *A Primer of Ecological Statistics.* Sinauer Associates, Inc., Sunderland, MA.
- Gotelli NJ. 2001. *A Primer of Ecology.* 3rd Ed. Sinauer Associates, Inc., Sunderland, MA Gupta RK. 2004. *Advances in Insect Biodiversity*. Agrobios,

Jodhpur.

- Krebs CJ. 1998. *Ecological Methodology*. 2nd Ed. Benjamin-Cummings Publ. Co., New York.
- Krebs CJ. 2001. *Ecology: The Experimental Analysis of Distribution and Abundance.* 5th Ed.Benjamin-Cummings Publ. Co., New York.
- Magurran AE. 1988. *Ecological Diversity and its Measurement.* Princeton Univ. Press, Princeton. Price PW. 1997. *Insect Ecology*. 3rd Ed. John Wiley, New York.
- Real LA and Brown JH. (Eds). 1991. *Foundations of Ecology: Classic Papers with Commentaries*. University of Chicago Press, Chicago.
- Schowalter Timothy D. 2011. *Insect Ecology – An Ecosystem Approach*. 3rd Ed. Academic Press, London, UK/ CA, USA.
- Southwood TRE and Henderson PA. 2000. *Ecological Methods.* 3rd Ed. Methuen and Co. Ltd., London.
- Speight MR, Hunta MD and Watt AD. 2006. *Ecology of Insects: Concepts and Application*. Elsevier Science Publ., The Netherlands.
- Townsend Colin R, Begon Michael and Harper John L. 2008.*Essentials of Ecology*.3rd Ed.Blackwell Publishing, USA/ UK/ Australia.
- Wilson EO, William H and Bossert WH. 1971.*A Primer of Population Biology*. Harvard University, USA.
- Wratten SD and Fry GLA. 1980. *Field and Laboratory Exercises in Ecology*. Arnold, London.

I. Course Title : Biological Control of Insect Pests and Weeds

II. Course Code : ENT 505

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To train the students with theory and practice of biological control, mass production techniques and field evaluation of various biological control agents like parasitoids, predators and various entomopathogenic microorganisms.

Theory

Unit I

History, principles and scope of biological control; important groups of parasitoids, predators and pathogens; principles of classical biological control-importation, augmentation and conservation. History of insect pathology, infection of insects by bacteria, fungi, viruses, protozoa, rickettsiae, spiroplasma and nematodes.

Unit II

Biology, adaptation, host seeking behaviour of predatory and parasitic groups of insects. Classification of parasitoids, important parasitoid families Role of insect pathogenic nematodes, viruses, bacteria, fungi, protozoa, etc., their mode of action. Biological control of weeds using insects. Epizootiology, symptomatology and etiology of diseases caused by the above and the factors controlling these. Defense mechanisms in insects against pathogens.

Unit III

Mass production of quality bio-control agents- techniques, formulations, economics, field release/ application and evaluation. Safety, Quality control and registration standards of entomopathogens

Unit IV

Successful biological control projects, future possibilities of biological control. Importation of natural enemies- Quarantine regulations, biotechnology in biological control. Semiochemicals in biological control.

Practical

Identification of common natural enemies of crop pests (parasitoids, predators, microbes) and weed killers; Visits to bio-control laboratories to learn rearing and mass production of egg, egg- larval, larval, larval-pupal and pupal parasitoids, common predators, microbes and their laboratory hosts, phytophagous natural enemies of weeds; Field collection of parasitoids and predators. Hands-on training in culturing, identification of common insect pathogens.

Learning outcome

Students are expected to have a good understanding of the role of natural enemies in managing pest populations below those causing economic damage. Learn the techniques for mass production of quality bio-agents and their optimal use in IPM.

Suggested Reading

- Burges HD and Hussey NW. (Eds). 1971. *Microbial Control of Insects and Mites.* Academic Press, London.
- De Bach P. 1964. *Biological Control of Insect Pests and Weeds.*Chapman and Hall, New York.
- Huffaker CB and Messenger PS. 1976.*Theory and Practices of Biological Control.*Academic Press, London.
- Ignacimuthu SS and Jayaraj S. 2003. *Biological Control of Insect Pests*. Phoenix Publ.,NewDelhi.
- Saxena AB. 2003. *Biological Control of Insect Pests*. Anmol Publ., New Delhi.

- Steinhaus EA(ed) 1963. Insect Pathology Vol 2 Academic Press London.
- Steinhaus EA 1984 Principles of Insect Pathology . Academic Press London
- Van Driesche and Bellows TS. Jr. 1996. *Biological Control*. Chapman and Hall, New York.

I. Course Title : Toxicology of Insecticides

II. Course Code : ENT 506

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To orient the students with structure and mode of action of important insecticides belonging to different groups, development of resistance to insecticides by insects, environmental pollution caused by toxic insecticides and their toxicological aspects.

V. Theory

Unit I

Definition and scope of insecticide toxicology; history of chemical control; pesticide use and pesticide industry in India.

Unit II

Classification of insecticides and acaricides based on mode of entry, mode of action and chemical nature; categorization of insecticides on the basis of toxicity – criteria for bees, beneficial insects and other insects in general; structure and mode of action of organochlorines, organophosphates, carbamates, pyrethroids, tertiary amines, New generation insecticides and their classification-diamides, neonicotinoids, oxadiazines, phenyl pyrozoles, compounds affecting energy metabolism, insect growth regulators, microbials, botanicals, new promising compounds/ new insecticide molecules; nanopesticides; drawbacks of insecticide abuse.

Unit III

Principles of toxicology; evaluation of insecticide toxicity; joint action of insecticides- synergism, potentiation and antagonism; factors affecting toxicity of insecticides; insecticide compatibility, selectivity and phytotoxicity. Bioassay definition, objectives, criteria, factors, problems and solutions.

Unit IV

Insecticide metabolism; insect-pest resistance to insecticides; mechanisms and types of resistance; insecticide resistance management and pestresurgence.

Unit V

Insecticide residues, their significance and environmental implications; procedures of insecticide residue analysis. Insecticide Act, registration procedures, label claim, and quality control of insecticides; Central Insecticide Board & Registration Committee-its function and duties- Label claim of pesticides-safe use of insecticides; diagnosis and treatment of insecticide poisoning.

VI. Practical

Insecticide formulations and mixtures; Laboratory and field evaluation of bio-efficacy of insecticides; Bioassay techniques; Probit analysis; Evaluationof insecticide toxicity; Toxicity to beneficial insects; Pesticide appliances; Working out doses and concentrations of pesticides; Procedures of residue analysis.

VII. Learning outcome

Students are expected understand the concept of toxicity, bio-efficacy,insecticide formulations, modes of action of insecticides, estimation of insecticide residues and have significant know-how about the functioning of various types of spray equipments.

VIII. Suggested Reading

- Chattopadhyay SB. 1985. *Principles and Procedures of Plant Protection.*Oxford and IBH, New Delhi.
- Dodia DA, Petel IS and Petal GM. 2008. *Botanical Pesticides for Pest Management*.Scientific Publisher (India), Jodhpur.
- Dovener RA, Mueninghoff JC and Volgar GC. 2002. Pesticides formulation and delivery systems: meeting the challenges of the current crop protection industry. ASTM, USA
- Gour T.B. and Sridevi D. 2012. *Chemistry, Toxicity and Mode of Action of Insecticides*. Kalyani Publishers, Ludhiana.
- Gupta HCL.1999. *Insecticides: Toxicology and Uses.* Agrotech Publ., Udaipur.
- Ishaaya I and Degheele (Eds.). 1998. *Insecticides with Novel Modes of Action.* Narosa Publ.House, New Delhi.
- Ishaaya I and Degheele D. 1998.*Insecticides with Novel Modes of Action: Mechanism and Application*. Norosa Publishing House, New Delhi.
- Kranthi K.R. 2005. *Insecticide Resistance*: *Monitoring, Mechanisms and Management Manual*. CICR, Nagpur.
- Krieger RI. 2001. *Handbook of Pesticide Toxicology*. Vol-II.Academic

Press. Orlando Florida. Mathews GA. 2002. *Pesticide Application Methods*.4th Ed. Intercept. UK.

- Matsumura F. 1985. *Toxicology of Insecticides.*Plenum Press, New York.
- Mohan M., Venkatesan T., Sivakumar G., Yandigeri M.S. and Verghese A. 2016. *Fighting Pesticide Resistance in Arthropods*. ICAR-NBAIR, Bengaluru.
- Otto D and Weber B. 1991.*Insecticides: Mechanism of Action and Resistance*. Intercept Ltd., UK.
- Pedigo LP and Marlin ER. 2009. *Entomology and Pest Management*, 6th Edition, Pearson Education Inc., Upper Saddle River, New Jersey 07458, U.S.A.
- Perry AS, Yamamoto I, Ishaaya I and Perry R. 1998.*Insecticides in Agriculture and Environment.*Narosa Publ. House, New Delhi.
- Prakash A and Rao J. 1997.*Botanical Pesticides in Agriculture.*Lewis Publication, New York.
- Roush R.T. 1990. *Pesticide Resistance in Arthropods*. Chapman and Hall, New York.
- Roy NK. 2006. *Chemistry of Pesticides*. Asia Printograph Shahdara Delhi.
- Whalon M.E., Mota-Sanchez D. and Hollingworth R.M. 2008. *Global Pesticide Resistance in Arthropods*. CABI, Oxfordshire.
- Yu S.J. 2014. *The Toxicology and Biochemistry of Insecticides* (2nd Ed.). CRC Press, Boca Raton

I. Course Title : Host Plant Resistance
II. Course Code : ENT 507
III. Credit Hours : 2 (1+1)

IV. Aim of the course

To orient the students with host plant resistance.

V. Theory

Unit I

History and importance of resistance; principles, classification, components, types and mechanisms of resistance.

Unit II

Insect-host plant relationships; theories and basis of host plant selection in phytophagous insects.

Unit III

Chemical ecology, tritrophic relations, volatiles and secondary plant substances; basis of resistance. Induced resistance – acquired and induced systemic resistance.

Unit IV

Factors affecting plant resistance including biotypes and measures to combat them.

Unit V

Screening techniques; breeding for insect resistance in crop plants; exploitationof wild plant species; gene transfer, successful examples of resistant cropvarieties in India and world.

Unit VI

Role of biotechnology in plant resistance to insects.

VI. Practical

Screening techniques for measuring resistance; Measurement of plant characters and working out their correlations with plant resistance;Testing of resistance in important crops;Bioassay of plant extracts of susceptible/ resistant varieties;Demonstration of antibiosis, tolerance and antixenosis.

VII. Learning outcome

Students are expected to acquire a thorough knowledge of the types and basis of mechanisms involved in host plant resistance, screening techniques to measure resistance and insect resistance breeding.

VIII. Suggested Reading

- Dhaliwal GS and Singh R. (Eds). 2004. *Host Plant Resistance to Insects -Concepts and Applications.* Panima Publ., New Delhi.
- Maxwell FG and Jennings PR. (Eds). 1980. *Breeding Plants Resistant to Insects.* John Wiley and Sons, New York.
- Painter RH. 1951. *Insect Resistance in Crop Plants*. MacMillan, London.
- Panda N and Khush GS. 1995. *Plant Resistance to Insects.* CABI, London.
- Sadasivam, S and Thayumanayan B. 2003. Molecular Host plant resistance to pests. CRC Press. P.496
- Smith CM. 2005.*Plant Resistance to Arthropods – Molecular and Conventional Approaches.*Springer, Berlin.

I. Course Title : Concepts of Integrated Pest Management

II. Course Code : ENT 508

III. Credit Hours : 2 (2+0)

IV. Aim of the course

To familiarize the students with principles of insect pest management, including concept and philosophy of IPM**.** Train students in computation of ETL and implementing IPM programmes.

V. Theory

Unit I

History, origin, definition and evolution of various terminologies. Concept and philosophy, ecological principles, economic threshold concept and economic consideration.

Unit II

National and international level crop protection organizations; Insecticide, regulatory bodies; synthetic insecticide, bio-pesticide and pheromoneregistration procedures; label claim of pesticides the pros and cons.

Unit III

Tools of pest management and their integration- legislative, quarantine regulations, cultural, physical and mechanical methods; host plant resistance, semiochemicals, chemical, biotechnological and bio-rational approaches in IPM. Pest survey and surveillance, forecasting, types of surveys including remote sensing methods, factors affecting surveys; political, social and legal implications of IPM; pest risk analysis; pesticide risk analysis; cost- benefitratios and partial budgeting; case studies of successful IPM programmes. ITK-s in IPM, area-wide IPM and IPM for organic farming; components of ecological engineering with successful examples. Artificial intelligence in IPM

Unit IV

Characterization of agro-ecosystems; sampling methods and factors affecting sampling; population estimation methods; crop loss assessment direct losses, indirect losses, potential losses, avoidable losses, unavoidable losses; global and Indian scenario of crop losses. Computation of EIL and ETL; cropmodeling; designing and implementing IPM system.

VI. Learning outcome

Students are expected to have significant knowledge of IPM concepts, estimation of losses due to insect pests, computation of ETL, EIL andshould be able take management decisions.

VII. Suggested Reading

- Dhaliwal GS and Arora R. 2003.*Integrated Pest Management – Concepts and Approaches*.Kalyani Publishers, New Delhi.
- HorowitzARandIshaayaI.2004.*InsectPestManagement:FieldandProtectedCrops*.Springer, NewDelhi.
- Ignacimuthu SS and Jayaraj S. 2007.*Biotechnology and Insect Pest Management*. Elite Publ., New Delhi.
- Norris RF, Caswell-Chen EP and Kogan M. 2002.*Concepts in Integrated Pest Management*.Prentice Hall, New Delhi.
- Pedigo RL. 2002. *Entomology and Pest Management.* 4th Ed. Prentice Hall, New Delhi.
- Subramanyam B and Hagstrum DW. 1995. *Integrated Management of Insects in Stored Products*.Marcel Dekker, New York.

I. Course Title : Pests of Field Crops

II. Course Code : ENT 509

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To familiarize the students about nature of damage and seasonal incidence of pestiferous insects that cause loss to major field crops and their effective management by different methods.

V. Theory

Systematic position, identification, distribution, host-range, bionomics, nature and extent of damage, seasonal abundance and management of insect and non-insect pests (mites, nematodes, rodents, birds, snails, slugs) and vectors. Insect pests scenario in relation to climate change.

Unit I

Polyphagous pests: grasshoppers, locusts, termites, white grubs, hairy caterpillars, and non-insect pests (mites, birds, rodents, snails, slugs, etc.). Pests of cereals and millets and their management.

Unit II

Pests of pulses, tobacco, oilseeds and their management.

Unit III

Pests of fibre crops, forage crops, sugarcane and their management.

VI. Practical

Field visits, collection and identification of important pests and their natural enemies; Detection and estimation of infestation and losses in different crops;

Study of life history of important insect and non insect pests.

VII. Learning outcome

Students are expected to acquire knowledge of insect pests of field crops, their nature of damage, life history traits and effective management.

VIII. Suggested Reading

- David, BV and Ramamurthy, VV. 2001. *Elements of Economic Entomology*. Popular Book Depot, Chennai.
- Dhaliwal GS, Singh R and Chhillar BS. 2006. *Essentials of Agricultural Entomology*. Kalyani Publishers, New Delhi.
- Dunston AP. 2007. *The Insects: Beneficial and Harmful Aspects*. Kalyani Publishers, New Delhi
- Evans JW. 2005. *Insect Pests and their Control*. Asiatic Publ., New Delhi.
- Nair MRGK. 1986. *Insect and Mites of Crops in India.* ICAR, New Delhi.
- Prakash I and Mathur RP. 1987. *Management of Rodent Pests.* ICAR, New Delhi.
- Saxena RC and Srivastava RC. 2007. *Entomology at a Glance*. Agrotech Publ. Academy,Udaipur.

I. Course Title : Pests of Horticultural and Plantation Crops
II. Course Code : ENT 510
III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart knowledge on major pests of horticultural and plantation crops regarding the extent and nature of loss, seasonal history, their integrated management.

V. Theory

Systematic position, identification, distribution, host range, biology, bionomics and seasonal abundance, nature and extent of damage and management of pests of various crops.

Unit I

Fruit Crops- mango, guava, banana, jack, papaya, pomegranate, litchi, grapes, ber, fig, citrus, aonla, pineapple, apple, peach and other temperate fruits.

Unit II

Vegetable crops- tomato, potato, radish, carrot, beetroot, cole crops. Cowpea, brinjal, okra, all gourds, drumstick, leafy vegetables, gherkin etc.

Unit III

Plantation crop- coffee, tea, rubber, coconut, arecanut, oil palm, date palm, cashew, cocoa, etc.; Spices and Condiments- pepper, cardamom, clove,nutmeg, cinnamon, chillies, turmeric, ginger, beetlevine, etc.

Unit IV

Ornamental plants, medicinal and aromatic plants and pests in polyhouses/ protected cultivation.

VI. Practical

Collection and identification of important pests and their natural enemies on different crops; Study of life history of important insect pests and non-insect pests.

VII. Learning outcome

Students are expected to acquire knowledge of insect pests of horticultural, medicinal and plantation crops, their nature of damage, life history traits and effective management.

VIII. Suggested Reading

- Atwal AS and Dhaliwal GS. 2002. *Agricultural Pests of South Asia and their Management.*Kalyani Publishers, New Delhi.
- Butani DK and Jotwani MG. 1984. *Insects and Vegetables.* Periodical Expert Book Agency, New Delhi.
- Dhaliwal GS, Singh R and Chhillar BS. 2006. *Essential of Agricultural Entomology.* Kalyani Publishers, New Delhi.
- Srivastava RP. 1997. *Mango Insect Pest Management.* International Book Distr., Dehra Dun.
- Verma LR, Verma AK and Goutham DC. 2004. *Pest Management in Horticulture Crops*: *Principles and Practices*. Asiatech Publ., New Delhi.

I. Course Title : Post Harvest Entomology

II. Course Code : ENT 511

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To focus on requirement and importance of grain and grain storage, to understand the role of stored grain pests and to acquaint with various stored grain pest management techniques for avoiding losses in storage.

V. Theory

Unit I

Introduction, history of storage entomology, concepts of storage entomology and significance of insect pests. Post-harvest losses *in toto vis-à-vis* total production of food grains in India. Scientific and socio-economic factors responsible for grain losses. Concept of seed vault.

Unit II

Important pests namely insects, mites, rodents, birds and microorganisms associated with stored grain and field conditions including agricultural products; traditional storage structures; association of stored grain insects with fungi and mites, their systematic position, identification, distribution, host range, biology, nature and extent of damage, role of field and cross infestations and natural enemies, type of losses in stored grains and their effect on quality including biochemical changes.

Unit III

Ecology of insect pests of stored commodities/ grains with special emphasis on role of moisture, temperature and humidity in safe storage of food grains and commodities. Stored grain deterioration process, physical and biochemical changes and consequences. Grain storage- types of storage structures i.e., traditional, improved and modern storage structures in current usage. Ideal seeds and commodities' storage conditions.

Unit IV

Important rodent pests associated with stored grains and their non-chemicaland chemical control including fumigation of rat burrows. Role of bird pestsand their management. Control of infestation by insect pests, mites and microorganisms. Preventive measures- Hygiene/ sanitation, disinfestations of stores/ receptacles, legal methods. Curative measures- Non-chemical control measures- ecological, mechanical, physical, cultural, biological and engineering. Chemical control- prophylactic and curative- Characteristics of pesticides, their use and precautions in their handling with special emphasis on fumigants. Insecticide resistance in stored product pests and its management; recent advances (MAS, PPP, HS) in storage pest management; integrated approaches to stored grain pest management.

VI. Practical

Collection, identification and familiarization with the stored grains/ seed insect pests and nature of damage caused by them; Detection of hidden insect infestation in stored food grains; Estimation of uric acid content in infested produce; estimation of losses in stored foodgrains; Determination of moisture content in stored foodgrains; Familiarization of storage structures, demonstration of preventive and curative measures including fumigation techniques;Treatment of packing materials and their effect on seed quality;Field visits to save grain campaign, central warehouse and FCI warehouses and institutions engaged in research or practice of grain storage like CFTRI, Mysore; IGSMRI, Hapur, etc. (only where logistically feasible).

VII. Learning outcome

Students are expected to acquire knowledge of pestiferous insects, mites, rats and birds affecting stored produce, their nature of damage, life history traits and effective management. Detection of insect infestation and familiarization with different storage structures.Learning preventive and curative measures to manage infestation in storage houses.

VIII. Suggested Reading

- Athanassiou A.G. and Arthur F.H. 2018. Recent Advances in Stored Product Protection. Springer
- Bhargava MC and Kumawat KC. 2010. Pests of Stored Grains and Their Management. New India Publishing, New Delhi.
- Hall DW. 1970. *Handling and Storage of Food Grains in Tropical and Subtropical Areas.* FAO. Agricultural Development Paper No. 90 andFAO, Plant Production and Protection Series No. 19, FAO,Rome.
- Hagstrum DW and Subramanyam B. 2006. Fundamentals of Stored-Product Entomology. AACC International
- Jayas DV, White NDG and Muir WE. 1995. *Stored Grain Ecosystem.* Marcel Dekker, New York.
- Khader V. 2004.*Textbook on Food Storage and Preservation*.Kalyani Publishers, New Delhi.

- Khare BP. 1994. *Stored Grain Pests and Their Management.*Kalyani Publishers, New Delhi.
- Rees D. 2007. Insects of Stored Grain. CSIRO Publishing, Australia.
- Subramanyam B and Hagstrum DW. 1995. *InterrelatedManagementof Insects in Stored Products.*Marcel Dekker, New York.
- Subramanyam B and Hagstrum DW. 2000. Alternatives to Pesticides in Stored Product IPM. Springer, New York.

I. **Course Title** : **Insect Vectors of Plant Pathogens**
II. **Course Code** : **ENT 512**
III. **Credit Hours** : **2 (1+1)**

IV. Aim of the course

To teach the students about the different groups of insects that act as vectors of plant pathogens, vector-plant pathogen interaction, and management of vectors for controlling disease

V Theory

UnitI

History of developments in the area of insects as vectors of plant pathogens. Important insect vectors and their characteristics; mouth parts and feeding processes of important insect vectors. Efficiency of transmission.

Unit II

Transmission of plant viruses and fungal pathogens. Relation between viruses and their vectors.

Unit III

Transmission of plant viruses by aphids, whiteflies, mealy bugs and thrips.

Unit IV

Transmission of mycoplasma and bacteria by leaf hoppers and plant hoppers.

Unit V

Transmission of plant viruses by psyllids, beetles and mites.Epidemiology and management of insect transmitted diseases through vector management.

VI Practical

Identification of common vectors of plantpathogens-aphids, leafhoppers, whiteflies, thrips, beetles, nematodes; Culturing and handling of vectors; demonstration of virus transmission through vectors- aphids, leafhoppers and whiteflies; Vector rearing and maintenance; Estimating vector transmission efficiency, studying vector-virus host interaction.

VII Learning outcome

Students are expected to be well versed with insect vectors of plant pathogens, acquire knowledge on disease transmission and vector management techniques.

VIII Suggested Reading

- Basu AN. 1995. *Bemisia tabaci* (Gennadius) – *Crop Pest and Principal Whitefly Vector of Plant Viruses.*Oxford and IBH, New Delhi.
- Harris KF and Maramarosh K. (Eds.). 1980. *Vectors of Plant Pathogens*. Academic Press, London.
- Maramorosch K and Harris KF. (Eds.). 1979. *Leafhopper Vectors and Plant Disease Agents*.Academic Press, London.
- Youdeovei A and Service MW. 1983. *Pest and Vector Management in the Tropics*. English Language Books Series, Longman, London.

I. Course Title : Principles of Acarology
II. Course Code : ENT513
III. Credit Hours : 2 (1+1)

IV. Aim of the course

To acquaint the students with external morphology of different groups of mites, train in identification of commonly occurring families of plant associated mites, provide information about important mite pests of crops and their management.

V. Theory

UnitI

History of Acarology; importance of mites as a group; habitat, collection and preservation of mites. Soil arthropods and their classification, habitats and their identification.

Unit II

Introduction to morphology and biology of mites and ticks.Broad classification- major orders and important families of Acari including diagnostic characteristics. Estimation of populations; sampling and extraction methods for soil arthropods.

Unit III

Economic importance, seasonal occurrence, nature of damage, host rangeof mite pests of different crops, mite pests in polyhouses, mite pests of stored products and honeybees. Management of mites using acaricides, phytoseiid predators, fungal pathogens, etc. Culturing of phytophagous, parasitic and predatory mites. Mode of action of acaricides, resistance of mites and ticks to acaricides, its management.

VI. Practical

Collection of mites from plants, soil and animals; Extraction of mites from soil, plants and stored products;Preparation of mounting media and slide mounts;External morphology of mites;Identification of mites up to family level using keys;Studying different rearing techniques for mites.

VII. Learning outcome

Students are expected to identify mites up to family level.

Acquire knowledge of mite pests of cultivated crops, their nature of damage, life history traits and effective management.

VIII. Suggested Reading

- Anderson JM and Ingram JSI. 1993. *Tropical Soil Biology and Fertility: A Handbook of Methods.*CABI, London.
- Chhillar BS, Gulati R and Bhatnagar P. 2007.*Agricultural Acarology*. Daya Publ. House, New Delhi.
- Dhooria, M. S. 2016. Fundamentals of Applied Acarology. Sprigner Nature Publication
- Dindal DL. 1990. *Soil Biology Guide*. A Wiley-InterScience Publ., John Wiley and Sons, New York.
- Gerson U and Smiley RL.1990. *Acarine Biocontrol Agents – An Illustrated Key and Manual*.Chapman and Hall, NewYork.
- Gupta SK. 1985. *Handbook of Plant Mites of India.*Zoological Survey of India, Calcutta.
- Gwilyn O and Evans GO. 1998. *Principles of Acarology*. CABI, London.
- Jeppson LR, Keifer HH and Baker EW. 1975. *Mites Injurious to Economic Plants*. University of California Press, Berkeley.
- Krantz GW. 1970. *A Manual of Acarology.* Oregon State Univ. Book Stores, Corvallis, Oregon.
- Pankhurst C, Dube Band Gupta,V. 1997. *Biological Indicators of Soil Health.* CSIRO, Australia.

- QiangZhiangZ.2003. *Mites of Green Houses-Identification, Biology and Control*. CABI, London.
- Sadana GL. 1997. *False Spider Mites Infesting Crops in India*.Kalyani Publishers House,New Delhi.
- Walter DE and Proctor HC. 1999. *Mites- Ecology, Evolution and Behaviou*r. CABI, London.
- Veeresh GK and Rajagopal D. 1988.*Applied Soil Biology and Ecology*. Oxford and IBH Publ.,New Delhi.

I. Course Title : Vertebrate Pest Management
II. Course Code : ENT514
III. Credit Hours : 2(1+1)

IV. Aim of the course

To impart knowledge on vertebrate pests like birds, rodents, mammals and others of different crops, their biology, damage they cause and management strategies.

V. Theory

UnitI

Introduction to vertebrate pests of different crops; biology of vertebrate pests such as rodents, birds and other mammals.

Unit II

Bio-ecology of birds of agricultural importance, patterns of pest damage and assessment, roosting and nesting systems in birds; management of pestiferous birds; conservation of predatory birds.

Unit III

Bio-ecology of rodents of agricultural importance, patterns of pest damage and assessment, burrowing pattern and habitat of rodents; management of pestiferous rodents.

Unit IV

Bio-ecology of higher vertebrates of agricultural importance, patterns of damage and assessment, their habitat; management of pestiferous vertebrates.

Unit V

Management strategies- physical (trapping, acoustics and visual), chemical (poisons, repellents, fumigants and anticoagulants), biological (predators, parasites), cropping practices, alteration of habitats, diversion baiting and other eco-friendly methods – Operational practices- baiting, equipments and educative programmes.

VI. Practical

Identification of important rodents, birds and other vertebrate pests of agriculture, food preference and hoarding; Social behaviour, damage assessment, field survey, population estimation, management strategies: preventive and curative methods.

VII. Learning outcome

Students are expected to be well versed with vertebrate pest diversity, their nature of damage, life history traits, behaviour and effective management.

VIII. Suggested Reading

- Ali S. 1965. *The Book of Indian Birds*. The Bombay Natural History Society, Bombay.
- Fitzwater WD and Prakash I. 1989.*Handbook of Vertebrate Pest Control*.ICAR, New Delhi.
- Prakash I and Ghosh PK. 1997.*Rodents in Indian Agriculture*. Vol. I. State of Art Scientific Publ., Jodhpur.
- Prakash I and Ghosh RP. 1987. *Management of Rodent Pests.* ICAR, New Delhi.
- Prater SH. 1971.*The Book of Indian Animals*. The Bombay Natural History Society, Bombay.
- Rahman A. 2020. *Protective and Productive Entomology* Narendra Publishing House, New Delhi

I. Course Title : Techniques in Plant Protection
II. Course Code : ENT515
III. Credit Hours : 1 (0+1)

IV. Aim of the course

To acquaint the students with appropriate use of plant protection equipments and techniques related to microscopy, Spectrophotometry, Chromatography.

V. Practical

Pest control equipments, principles, operation, maintenance, selection, and application of pesticides;Seed dressing, soaking, root-dip treatment, dusting, spraying, and pesticide application through irrigation water; Application of drones in plant protection; Soil sterilization, solarization, techniques to check the spread of pests through seed, bulbs, corms, cuttings and cutflowers;Uses of light, transmission and scanning electron microscopy; Protein isolation from the pest and host plant and its quantification using spectrophotometer and molecular weight determination using SDS/ PAGE; Use of tissue culture techniques in plant protection; Application of soil fumigants. Spectrophotometry, Chromatography – HPLC, LCMS, NMR , Molecular docking etc. Visit and exposure to Research laboratories to familiarize with Instrumental analysis

VI. Learning outcome

Students are expected to have a good knowledge of different plant protection equipments and techniques related to pestforecasting.

VII. Suggested Reading

- Alford DV. 1999. *A Textbook of Agricultural Entomology.* Blackwell Science, London.
- Crampton JM and Eggleston P. 1992. *Insect Molecular Science.* Academic Press, London.

I. Course Title : Apiculture
II. Course Code : ENT 516
III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart knowledge about the honey bees, and their behaviour and activities; bee husbandry, bee multiplication, bee enemies and diseases and their management; hive products, apitherapy; and managed bee pollination of crops

V. Theory

Unit I

Historical development of apiculture at global level and in India; Classification of bees; global distribution of genus *Apis* and races; Morphology and anatomy of honey bee; Honey bee biology, ecology, adaptations; Honey bee behaviour – nest founding, comb construction, brood care, defense, other in- house and foraging activities; Bee pheromones; Honey bee communication.

Unit II

Commercial beekeeping as an enterprise; Design and use of bee hives; Apicultural equipment; Seasonal bee husbandry; Honey bee nutrition and artificial diets; Absconding, swarming, drifting – causes and management; Curbing drone rearing; Laying worker menace – causes, signs and management.

Unit III

Bee genetics; Principles and procedures of bee breeding; Screening of honey bee colonies; Techniques in mass queen bee rearing; Mating nuclei and their establishment; Selective mating; Queen bee management; Bee packages.

Unit IV

Ectoparasitic and endoparasitic bee mites – biology, ecology, nature and symptoms of damage, management tactics; Wax moths, wasps and ants – biology, ecology, nature and symptoms of damage, management tactics; Predatory birds, their damage potential and management tactics; Pesticide poisoning to honey bees, signs and protection; Protocols in evaluation of pesticide toxicity to honey bees.

Unit V

Honey – composition, properties, crystallization, post-harvest handling and processing; Honey quality standards and assessment; Apicultural diversification – potential and profitability; Production/ collection of bee pollen, propolis, royal jelly, bee venom and bees wax and their post-harvest handling; Apitherapy; Value addition of hive products; Development of apiculture project.

Unit VI

Non-*Apis* pollinators, their augmentation and conservation; Role of bee pollinators in augmenting crop productivity; Managed bee pollination of crops.

VI. Practical

Morphological characteristics of honeybee; Mouthparts; digestive, respiratory and reproductive adaptations in different castes of honeybees; Recording of colony performance; Seasonal bee husbandry practices; Swarming, queenlessness, swarming, laying workers menaces, etc. and their remedies; Innovative techniques in mass queen bee rearing; selection and breeding of honey bees; Instrumental insemination; formulation of artificial diets and their feeding; Production technologies for various hiveproducts; Bee enemies and diseases and their management; Recording pollination efficiency; Application of various models for determining pollination requirement of crop; Developing a beekeeping project.

VII. Learning outcome

Students are expected to have a comprehensive knowledge of bee biology, physiology and bee keeping/apiculture.

With practical training it is expected that students develop entrepreneurial skills for apiculture.

VIII. Suggested Reading

- Abrol DP and Sharma D. 2009. *Honey Bee Mites and Their Management.* Kalyani Publishers, New Delhi,India.
- Abrol DP. 2009. *Honey bee Diseases and Their Management*. Kalyani Publishers, New Delhi, India.
- Abrol DP. 2010. *Beekeeping: A Compressive Guide to Bees and Beekeeping*. Scientific Publishers, India.
- Abrol DP. 2010. *Bees and Beekeeping in India*. Kalyani Publishers, New Delhi, India.
- Abrol DP. 2012. *Pollination Biology: Biodiversity Conservation and Agricultural Production.*Springer.
- Atwal AS. 2001. *World of Honey Bees.* Kalyani Publishers, New Delhi-Ludhiana, India.
- Atwal AS. 2000. *Essentials of Beekeeping and Pollination*. Kalyani Publishers, New Delhi-Ludhiana, India.
- Bailey L and Ball BV. 1991. *Honey Bee Pathology*. Academic Press, London.
- Crane Eva and Walker Penelope. 1983. *The Impact of Pest Management on Bees and Pollination.* Tropical Development and Research and Institute, London.
- Free JB. 1987. *Pheromones of Social Bees.* Chapman and Hall, London.
- Gatoria GS, Gupta JK, Thakur RK and Singh Jaspal. 2011. *Mass Multiplication of Honey Bee Colonies.* ICAR, New Delhi, India.
- Grahm Joe M. 1992.*Hive and the Honey Bee.*Dadant & Sons, Hamilton, Illinois, USA.
- Grout RA. 1975. *Hive and the Honey Bee.* Dadant & Sons, Hamilton, Illinois, USA.
- HolmE.1995.*QueenRearingGeneticsandBreedingofHoneyBees.*Gedved, Denmark.
- Laidlaw HH Jr and Eckert JE. 1962. *Queen Rearing*. Berkeley, University of California Press.
- Laidlaw HH. 1979. *Contemporary Queen Rearing.* Dadant & Sons, Hamilton, Illinois, USA.
- Mishra RC. 2002. *Perspectives in Indian Apiculture*. Agro-Botanica, Jodhpur,India.

- Mishra RC. 1995. *Honey Bees and their Management in India.* I.C.A.R., New Delhi, India.
- Morse AA. 1978. *Honey Bee Pests, Predators and Diseases*. Cornell University Press, Ithaca and London.
- Rahman, A. 2017.*Apiculture in India*, ICAR, New Delhi
- Ribbands CR. 1953.*The Behaviour and Social Life of Honey Bees*. Bee Research Association Ltd., London, UK.
- Rinderer TE. 1986. *Bee Genetics and Breeding.* Academic Press, Orlando.
- Sardar Singh. 1962. *Beekeeping in India*. I.C.A.R., New Delhi, India (Reprint: 1982).
- Seeley TD. 1985. *Honey Bee Ecology*. Princeton University Press, 216 pp.
- Snodgrass RE. 1925. *Anatomy and Physiology of the Honey Bee*. Mc Graw Hill Book Co., New York &London.
- Snodgrass RE. 1956. *Anatomy of the Honey Bee*. Comstock Publishing Associates, Cornell Univ. Press, Ithaca, New York.

I. Course Title : Sericulture
II. Course Code : ENT 517
III. Credit Hours : 3 (2+1)

IV. Aim of the Course

To familiarize the students with entrepreneurial opportunities in entomology, sericulture in particular, and providing information on silk worm rearing, production and management.

V. Theory

Unit I

History of Sericulture, importance, organizations involved in sericulture activities, silkworm types, characteristic features of different silkworms, distribution, area and silk production.

Unit II

Mulberry species, ecological requirements, cultivation, improved varieties, propagation methods, sapling production, planting and pruning techniques; pest and diseases, management strategies; intercropping, water and weed management. Food plants of eri silkworm, castor cultivation, intercultural operations, nutrient and water management; method of harvest; host plants of Tasar, nursery and cultivation, selection of seed, soaking and heap making, pruning techniques. Food plants of Muga silkworm, Som and Soalu propagation methods; nursery techniques; intercultural operations and weed management.

Unit III

Silkworm origin – classification based on voltinism, moultinism, geographical distribution and genetic nature – pure races –multivoltine and bivoltine races – cross breeds – bivoltine hybrids –Races and hybrids of mulberry, eri, tasar and muga silkworm- Morphology and biology of silkworm, sex limited characters; anatomy of digestive and excretory systems of larva; structure and function of silk glands.

Unit IV

Rearing house, types, Rearing appliances disinfection, room and bed disinfectants; egg incubation methods, Chawki rearing, feeding, cleaning and spacing; rearing of late age worms, feeding, cleaning, spacing and moulting care; mountages, cocoon harvesting and marketing; pests and diseases of silkworms and their management. Marketing and Recent advances in sericulture

Unit V

Post cocoon technology, stifling, cocoon cooking, brushing, reeling, re-reeling, bleaching, degumming, dyeing, printing and weaving, different reeling machines; value addition in sericulture; economics of sericulture.

VI. Practical

Morphology of mulberry plants; Identification of popular mulberry genotypes; Nursery bed and main field preparation; Planting methods;Identification of nutrient deficiency symptoms; Pruning and harvesting methods;Identification of pests and diseases of mulberry, *Terminalia arjuna, Terminalia tomentosa,* Som and Soalu- Nursery and pruning techniques – Intercultural operations;

Morphology of silkworm – Identification of races – Dissection of mouth parts and silk glands – Disinfection techniques – rearing facilities – silkworm rearing – feeding, cleaning and spacing – Identification of pests and diseases of mulberry silkworm – hyperparasitoids and mass multiplication techniques – silkworm egg production technology –Tasar, Eri and muga silkworms – rearing methods–pests and diseases of non-mulberry silkworms – Visit to grainage, cocoon market and silk reeling centre – Economics of silkworm rearing.

VII. Learning outcome

Students taking up sericulture are expected to have a thorough knowledge of silkworm morphology, races, biology, and all the practices of rearing for silk production.

They should be well versed with the pests and diseases of silkworm and their management.

With practical training it is expected that students develop entrepreneurial skills for sericulture or link up with industries to sell cocoons for silk production or guide farmers engaged in silk worm rearing/ sericulture.

VIII. Suggested Reading

- Dandin SB and K Giridhar. 2014. Hand book of Sericulture Technologies. Central Silk Board, Bangalore, 423p.
- Govindaiah G, VP, Sharma DD, Rajadurai S and Nishita V Naik. 2005. A text book on mulberry crop protection. Central Silk Board, Bangalore.450 p.
- Jolly MS, Sen SK, Sonwalkar TN and Prasad GK. 1980. Non– mulberry Silks. FAO Agicultural Services Bulletin 29. Food and Agriculture Organization of the United Nations, Rome, 178 p.
- Mahadevappa D, Halliyal VG, Shankar DG and Ravindra Bhandiwad. 2000. Mulberry Silk Reeling Technology. Oxford and IBH Publishing Co. Pvt. Ltd, NewDelhi. 234p.
- Mohanty PK. 2003. Tropical wild cocoons of India. Daya Publications, Tri Nagar, New Delhi, 197 p.
- Nataraju B, Sathyaprasad K, Manjunath D and Kumar A. 2005.Silkworm crop protection.CSB, Bangalore. 412 pp.
- Rangaswami G, Narasimhanna MN, Kasiviswanathan K, Sastry CR and Jolly MS. 1976. Food Plants of non-mulberry silkworms. In: *Mulberry cultivation*. FAO Agricultural Services Bulletin.Vol.1, Chapter-13. Rome, Italy. 96 p.
- Tribhuvan Singh and Saratchandra B. 2004. Principles and Techniques of silkworm seed production. Discovery publishing House, New Delhi, 360 pp.

IX. E-resources

www.silkwormgenomics.org; www.silkboard.com; ww.silkgermplasm.com; www.csrtimys.res.in

I. Course Title : Lac Culture

II. Course Code : ENT 518

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To familiarize the students with entrepreneurial opportunities in entomology with an emphasis on lac culture in particular. To provide information on lac insect rearing, production and management.

V. Theory

Unit I

History of lac production; importance, potential of lac production in India; organizations involved in lac production activities; strains of lacinsects and lac crops – distribution, area and production of different strains of lac.

Unit II

Steps and operation of lac production; lac host plant species, ecological requirements, their cultivation; seasons of host plants, harvest time of host plants,rearingseasons; grouping of host trees, pruning methods, timing; lac host plant pests and diseases; management strategies.

Unit III

Basic morphology and taxonomy of lac insect, strains of lac insect and their characteristics; composition of lac; biology of lac insect, species diversity and distribution.

Unit IV

Introduction, lac insect-host plant interaction; selection of brood lac, local practices, improved alternatives, coupe system; propagation of lac insects: natural self inoculation, artificial inoculation; inoculation process and duration; removal of phunki, harvesting of lac, immature harvesting, mature harvesting and time of harvesting. Predators and parasitoids of lac insect, hyperparasites, diseases and their management.

Unit V

Lac production stages; factors affecting yield and quality of shellac. Pure stock of host plants (kusum, palas, ber, pigeonpea, semialata) ;alternative method; technology of brood preserving. Host-specific technologies – cultivation on specific host plants; integration of lac cultivation with agro-forestry and horticulture; socio-economic potential of lac; export-import of lac/ lac products; marketing of lac and its products. Lac processing and value addition; entrepreneurship development.

VI. Practical

Lac host cultivation and lac production practices; Equipments for lac production; Conventional and advanced methods; Coupe system of lac production; Cultivation of suitable host plants; Pruning of host trees;Herbarium of host plants; Strains of lac insects; Brood lac selection and treatment for pest management; Slide preparation of adult and immature stages; Inoculation of host tree; Identification of natural enemies of lac insect and their management; Molecular characterization of lac insect; Harvesting; Process of manufacture of seed lac, shell lac from stick lac; Grading of seed lac and shellac; Marketing of lac products and byproducts.

VII. Learning outcome

- The students are expected to have good knowledge of lac host trees and their maintenance for lac production.
- It is expected that they should perfect the most suitable techniques for lac producton with a good knowledge about diseases and natural enemies of the lac insect.
- With practical training it is expected that students are able to guide landless labourers, who bring stick lac as forest produce.

VIII. Suggested Reading

- David BV and Ramamurthy VV. 2011.*Elements of Economic Entomology*, 6th Edition, Namrutha Publications, Chennai.
- Sharma KK and Ramani S. 2010.*Recent advances in lac culture*. ICAR-IINRG, Ranchi.

I. Course Title : Molecular Approaches In Entomology
II. Course Code : ENT 519
III. Credit Hours : 3 (2+1)
IV. Aim of the course

To acquaint students the latest techniques used in molecular biology.

V. Theory

Unit I

Introduction to molecular biology, Historical perspective of molecular entomology, techniques used in molecular biology.

Unit II

DNA recombinant technology, identification of genes/ nucleotide sequences for traits of interest, techniques of interest in plants and microbes.

Unit III

Genes of interest in entomological research- marker genes for sex identification, peptides and neuro peptides, JH esterase, St toxins and venoms, chitinase, Plant derived enzyme inhibitors, protease inhibitors, trypsin inhibitors, á-amylase inhibitors, lectins, terepenes and terpenoids;

Unit IV

Genetically engineered microbes -Genetic engineering in baculoviruses and fungal biocontrol agents for greater efficacy against insect pests. *Bacillus thuringiensis* endotoxins, mode of action of cry genes, classification and properties, synthetic Bt toxin genes Transgenic plants for pest resistance. Effects of transgenic plants on pest biology and development, resistance management strategies in transgenic crops, molecular mechanism of insecticide resistance

Unit V

Genetic-based methods for agricultural insect pest management, insect pest management through sterile insect technique and release of insects carrying a dominant lethal gene. Methods and application of insect trangenesis, transgenics in silkworm and honeybees. Molecular tools for taxonomy and phylogeny of insect pests, DNA-based diagnostics. Nano technology and its application. Importance of bioinformatics in molecular biological experiments

VI Practical

Isolation of DNA/RNA; Agarose gel electrophoresis of DNA, quantification of DNA by spectrophotometirc and agarose gel analysis, PCR amplification of mitochondrial cytochrome oxidase subunit I gene (cox1) and 16S rRNA gene, cloning of PCR amplicons in standard plasmid vectors for sequencing, confirmation of the insert, miniprep of recombinant plasmid DNA, BLAST analysis and multiple sequence alignment of the sequence with sequences already available in GenBank; Isolation of host plant proteins, SDS-PAGE of the isolated proteins.

VII Learning outcome

The students are expected to be well versed with the basic techniques used in molecular biology.

Students are expected to have firsthand knowledge of the molecular approaches employed in Entomology with hand on experience with the basic techniques.

VIII Suggested Reading

- Bhattacharya TK, Kumar P and Sharma A. 2007.*Animal Biotechnology*. 1st Ed., Kalyani Publication, New Delhi.
- Hagedon HH, Hilderbrand JG, Kidwell MG and Law JH. 1990. *Molecular Insect Science.* Plenum Press, New York.
- Hoy MA. 2003. *Insect Molecular Genetics: An Introduction to Principles and Applications*. 2nd Ed. Academic Press, NewYork.
- Oakeshott J and Whitten MA. 1994. *Molecular Approaches to Fundamental and Applied Entomology.* Springer Verlag.
- Rechcigl JE and Rechcigl NA. 1998. *Biological and Biotechnological Control of Insect Pests.*Lewis Publ., North Carolina.
- Roy U and Saxena V. 2007.*A Hand Book of Genetic Engineering*. 1st Ed., Kalyani Publishers, New Delhi.
- Singh BD. 2008. *Biotechnology (Expanding Horizons)*.Kalyani Publishers, New Delhi.
- Singh P. 2007.*Introductory to Biotechnology*. 2nd Ed. Kalyani Publishers, New Delhi.

I. Course Title : Plant Quarantine, Biosafety and Biosecurity

II. Course Code : ENT 520

III. Credit Hours : 2 (2+0)

IV. Aim of the course

To acquaint the learners about the principles and the role of Plant Quarantine in containment of pests and diseases, plant quarantine regulations and set-up.Also, to facilitate students to have a good understanding of the aspects of biosafety and biosecurity.

V. Theory

Unit I

Definition of pest, pesticides and transgenics as per Govt. notification; relative importance; quarantine – domestic and international.Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case histories of exotic pests/ diseases and their status.

Unit II

Plant protection organization in India. Acts related to registration of pesticides and transgenics. Insecticide regulatory bodies, synthetic insecticides, bio-pesticides and pheromone registration procdures. History of quarantine legislations, PQ Order 2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

Unit III

Identification of pest/ disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniques to detect pest/ pathogen infestations; VHT and other safer techniques of disinfestation/ salvaging of infected material.

Unit IV

WTO regulations; non-tariff barriers; pest risk analysis, sanitary and phytosanitary measures. Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/ disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity. Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, issues related to release of genetically modified crops.

VI. Learning outcome

Students are expected to have a good knowledge on the rules and regulations of Plant Quarantine, WTO regulations, GAP, Sanitary and Phytosanitary measures.

VII. Suggested Reading

- Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.
- Rhower GG. 1991. Regulatory Plant Pest Management. In: *Handbook of Pest Management in Agriculture*. 2nd Ed. Vol. II. (Ed. David Pimental), CRC Press.
- Shukla A and Veda OP. 2007.*Introduction to Plant Quarantine*. Samay Prakashan, New Delhi.

I. **Course Title** : **Edible and Therapeutic Insects**
II. **Course Code** : **ENT 521**
III. **Credit Hours** : **2(1+1)**

IV. **Aim of the course**

To create awareness and acquaint students about the contribution that insects make to ecosystems, diets, food security and livelihoods indeveloped and developing countries.

V. **Theory**

Unit I

Edible and therapeutic insects: the concept, definition, and importance.

Unit II

History and origin of insects as food, feed and medication; important insect species and insect products consumed.

Unit III

Edible insect ecology, conservation and management of edible insect resources; environmental opportunities of insect rearing.

Unit IV

Nutritional composition and role of insects in food security.

Unit V

Insect farming: the concept, definitions, and rearing techniques.

Unit VI

Processing edible insects for food and feed.

Unit VII

Food safety and preservation, edible insects for livelihood security.

VI. **Practical**

Survey and identification of edible and therapeutic insect species; Collection and preservation of edible and therapeutic insect specimens; Rearing techniques of edible insect species;Harvesting techniques of edible insects from natural environment; Analysis of proximate elemental composition, antioxidant and anti-nutritional properties and microbial aspects of preservation.

VII. **Learning outcome**

Students are expected to be aware of insects for edible and therapeutic use; their nutritional composition. Should know the techniques of farming and processing insects for human and animal consumption.

VIII. **Suggested Reading**

- Halloran A, Flore R, Vantomme P and Roos N 2018.Edible insects in

sustainable food systems.

- Van Huis A, Itterbeeck JK, Klunder H, Mertens E, Halloran A, Muir G and Vantomme. 2013.Edible insects: future prospects for food and feed security. Food and Agricultural Organization of the United Nations, Rome.

I. Course Title : Medical and Veterinary Entomology

II. Course Code : ENT 522

III. Credit Hours : 2(1+1)

IV. Aim of the course

To study the major insect, mite, and tick vectors of disease to man and animals. Students will learn to identify and understand the life cycles, morphology, and behavior of mosquitoes, ticks, mites, lice, fleas, and other disease vectors.

V. Theory

Unit I

Introduction to medical, veterinary and forensic entomology; Classification of Arthropod-borne diseases; Hematophagy, disease transmission and epidemiology; flies (Diptera) of medical and veterinary Importance; moth flies: Leishmaniasis and Bartonellosis; biting midges (Ceratapogonidae).

Unit II

Mosquito taxonomy, biology, and behavior; mosquito viruses: EEE, VEE, SLE, yellow fever,mosquito surveillance; malaria; horse flies, deer flies: EIA, anaplasmosis; muscid flies; Myiasis (Muscoidea); myiasis and louse flies; black flies of medical and veterinary Importance; filariasis: mansonellosis, onchocerciasis.

Unit III

Lice of medical and veterinary importance; rickettsial diseases: epidemic typhus, etc.; mites: rickettsial pox; mites and acariasis: mange, scabies, chiggers; spiders and scorpions; fleas (Siphonaptera) of medical and veterinary importance; plague and murine typhus.

Unit IV

Ticks of medical and veterinary importance; lyme disease, rocky mountain spotted fever, tularemia; true bugs (Hemiptera): kissing bugs and bedbugs; chagas disease; tsetse flies; Lepidoptera and Hymenoptera of medical and veterinary importance.

VI. Practical

Identification of arthropod Classes, Orders and Families of medical and veterinary importance; Collection, segregation, curing insect and arachnid specimens, their preservation; Management of insect and mite pests of medical and veterinary importance; Study of some practical aspects in forensic entomology.

VII. Learning outcome

Students are expected to identify the arthropods of medical and veterinary importance; identify the diseases transmitted by these arthropod vectors and suggest management options.

VIII. Suggested Reading

- David BV and Ramamurthy VV.2011. *Elementsof Economic Entomology*, 6th Edition, Namrutha Publications,Chennai.
- Gullan PJ and Cranston PS. 2010.*The Insects: An Outline of Entomology*. 4th Edition, Wiley-Blackwell, West Sussex, UK & New Jersey, US.
- Mullen G and Durden L. 2018. *Medical and Veterinary Entomology*, 3rd Edition, Academic Press.

I. Course Title : Forest Entomology
II. Course Code : ENT523
III. Credit Hours : 2 (1+1)

IV. Aim of the course

To promote a more global theoretical understanding of pest population dynamics and the causes of forest insect outbreaks: covering pests of both natural forests and plantations, the diversity of tropical forest insects, their ecological functions, the concept of pests and the incidence of pests in natural forests, plantations and stored timber.

V. Theory

Unit I

Introduction to forestry in the tropics, tropical forests: characteristics and types of tropical forests, management of tropical forests and the problems in their management; plantation forestry: beginnings, expansion and current status.

Unit II

History of tropical forest entomology, diversity of forest insects: structural and functional diversity – the feeding guilds, concept of pests, ecology of insects in forest environment, concept and functioning of ecosystem, role of insects in ecosystem processes of tropical forests: insects as primary consumers,secondary and tertiary consumers, as decomposers, as food, pollinators and other ecological interactions.

Unit III

Insect pests in natural forests, general pest incidence, pest outbreaks: Lepidoptera, Coleoptera, Hemiptera, and Hymenoptera; insect pests in plantations, nursery pests, sapling pests, pests of older plantations and their impact; insect pests of stored timber, categories of wood destroying insects and their damage: termites and beetles. Pests of major agroforestry trees like Teak, Mahagony, Ailanthus. Pests of bamboos and reeds in field and storage

Unit IV

Population dynamics, characteristics of population growth, factors affection population growth, principles governing population dynamics, types and causes of forest insect outbreaks; general issues in forest entomology: enemies' hypothesis, resource concentration hypothesis, pest evolution hypothesis; pest problems in plantations of indigenous *vs* exotic species; pest problems in monocultures *vs* mixed plantations.

Unit V

Management of tropical forest insect pests, historical development and present status of tropical forest pest management, overview of pest managementoptions: preventive measures, remedial measures; unique features of forest pest management; constraints to forest pest management in the tropics; guidelines for the practice of forest pest management in the tropics.

Unit VI

Insect pests in plantations: Location-specific case studies.

VI. Practical

Collection, identification and preservation of important insect pest specimens of forest plants and some damagematerial; Detection of insect infestation and assessment of losses due to insect pests; Habitat management for vertebrate and insect pests; Fire control methods and devices; Familiarization with the meteorological and plant protection equipment, application of pesticides and bio-control agents in the management of insect pests in nurseries and plantations.

VII. Learning outcome

Students are expected to acquire knowledge of insect pests of forest nurseries, forests and plantations, their nature of damage, life history traits and effective management.

Likewise, students are expected to have a thorough knowledge of pestiferous insects of stored timber, hide and other forest produce.

VIII. Suggested Reading

- Jha LK and Sen Sarna PK. 1994. *Forest Entomology*. Ashish Publishing House, Delhi.
- Nair KSS. 2007. *Tropical Forest Insect Pests: Ecology, Impact, and Management*, Cambridge University Press, Edinburgh/ New York.
- Stebbings EP. 1977. *Indian Forest Insects*. JK Jain Brothers.

Course Title with Credit Load for Ph.D in Agricultural Entomology

Course code	Course title	Credit Hours
ENT 601	Insect Phylogeny and Systematics	3 (1+2)
ENT 602**	Insect Physiology and Nutrition	3 (2+1)
ENT 603	Insect Ecology and Diversity	3 (2+1)
ENT 604	Insect Behaviour	2 (1+1)
ENT 605**	Bio-inputs for Pest Management	3 (2+1)
ENT 606**	Insecticide Toxicology and Residues	3 (2+1)
ENT 607	Plant Resistance to Insects	2 (1+1)
ENT 608	Acarology	2 (1+1)
ENT 609	Molecular Entomology	2 (1+1)
ENT 610	Integrated Pest Management	2 (2+0)
ENT 691	Doctoral Seminar – I	1 (0+1)
ENT 692	Doctoral Seminar – II	1 (0+1)
ENT 699	Doctoral Research	75 (0+75)

**Core courses for Doctoral programme

I. Course Title : Insect Phylogeny and Systematics

II. Course Code : ENT 601

III. Credit Hours : 3 (1+2)

IV. Aim of the course

To familiarize the students with different schools of classification, phylogenetics, classical and molecular methods, evolution of different groups of insects. Detailed study about the International Code of Zoological Nomenclature;ethics and procedure for taxonomic publications.

V. Theory

Unit I

History of taxonomy. Detailed study of three schools of classification- numerical, evolutionary and cladistic. Methodologies employed. Development of phenograms, cladograms, molecular approaches for the classification of organisms.Methods in identification of homology. Species concepts, speciation processes and evidences. Zoogeography.

Unit II

Detailed study of International Code of Zoological Nomenclature, including appendices to ICZN; scientific ethics.

Unit III

Concept of Phylocode and alternative naming systems for animals. A detailed study of selected representatives of taxonomic publications – small publications of species descriptions, works on revision of taxa, monographs, check lists, faunal volumes, etc. Websites related to taxonomy and data bases.

Unit IV

Molecular taxonomy, barcoding species and the progress made in molecular sytematics.

VI. Practical

Collection, curation and study of one taxon of insects- literature search, compilation of a checklist, study of characters, development of character table, and construction of taxonomic keys for the selected group; Development of descriptions, photographing, writing diagrams, and preparation of specimens for "type like" preservation, Submission of the collections made of the group; Hands on training in DNA isolation, sequencing etc. Multivariate analysis techniques for clustering specimens into different taxa, and development of phenograms; Rooting and character polarization for developing cladograms and use of computer programmes to develop cladograms.

VII. Learning outcome

Scholars are expected to understand the concepts of taxonomic hierarchy, study taxonomic characters, variations, intra-specific phenotypic plasticity; prepare taxonomic keys for specific groups and write taxonomic papers and reviews.

Scholars should be able to identify insects of economic importance up to family/ generic levels and specialize in any one group of insects up to species level identification.

VIII. Suggested Reading

- CSIRO 1990.*The Insects of Australia: A Text Book for Students and Researchers.* 2nd Ed. Vols.I and II, CSIRO. Cornell Univ. Press, Ithaca.
- Dakeshott J and Whitten MA. 1994. *Molecular Approaches to Fundamental and Applied Entomology.* Springer-Verlag, Berlin.
- Freeman S and Herron JC. 1998. *Evolutionary Analysis*. Prentice Hall, New Delhi.

- Hennig W. 1960. *Phylogenetic Systematics*. Urbana Univ. Illinois Press, USA.
- Hoy MA. 2003. *Insect Molecular Genetics: An Introduction to Principles and Applications*. 2nd Ed. Academic Press, New York.
- Mayr E and Ashlock PD. 1991.*Principles of Systematic Zoology*.2nd Ed. McGraw Hill, New York.
- Mayr E.1969. *Principles of Systematic Zoology*.McGraw-Hill, New York.
- Quicke DLJ. 1993. *Principles and Techniques of Contemporary Taxonomy*. Blackie Academic and Professional, London.
- Ross HH. 1974. *Biological Systematics.* Addison Wesley Publ. Co., London.
- Verma, A. 2015.Principles of Animal Taxonomy. Narosa Publishing House, New Delhi.
- Wiley EO. 1981. *Phylogenetics: The Theory and Practices of Phylogenetic Systematics for Biologists*. Columbia Univ. Press, USA.

I. Course Title : Insect Physiology and Nutrition

II. Course Code : ENT 602

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart knowledge to the students on detailed physiology of various secretory and excretory systems, moulting process, chitin synthesis, physiology of digestion, transmission of nerve impulses, nutrition of insects, pheromones, etc.

V. Theory

Unit I

Physiology and biochemistry of insect cuticle and moulting process. Biosynthesis of chitin, chitin-protein interactions in various cuticles, hardening of cuticle.

Unit II

Digestive enzymes, digestive physiology in phytophagous, wood boring and wool feeding insects, efficiency of digestion and absorption, role of endosymbionts in insect nutrition, nutritional effects on growth and development; physiology of excretion and osmoregulation, waterconservation mechanisms.

Unit III

Detailed physiology of nervous system, transmission of nerve impulses, neuro- transmitters and modulators. Production of receptor potentials in different types of sensilla, pheromones and other semiochemicals in insect life, toxins and defense mechanisms.

Unit IV

Endocrine system and insect hormones, physiology of insect growth and development- metamorphosis, polymorphism and diapause. Insect behaviour in IPM- Concept of super-normal stimuli and behavioural manipulation as potential tool in pest management, use of semio-chemicals, auditory stimuli and visual signals in pest management.

VI. Practical

Preparation of synthetic diets for different groups of insects; Rearing of insects on synthetic, semi-synthetic and natural diets; Determination of co-efficient of utilization; Qualitative and quantitative profile of bio-molecules: practicing analytical techniques for analysis of free amino acids of haemolymph; Zymogram analyses of amylase; Determination of chitin in insect cuticle; Examination and count of insect haemocytes.

VII. Learning outcome

Thescholarsareexpectedtohavethoroughtheoreticalandpracticalknowledgeo f insect physiology that can be made use of in practical/applied entomological aspects.

Understand how physiological systems in insects are integrated to maintain homeostasis.

VIII. Suggested Reading

- Ananthkrishnan TN. (Ed.). 1994. *Functional Dynamics of Phytophagous Insects*. Oxford and IBH, New Delhi.
- Bernays EA and Chapman RF. 1994.*Host-Plant Selection by Phytophagous Insects*. Chapman and Hall, London.
- Kerkut GA and Gilbert LI. 1985.*Insect Physiology, Biochemistry and Pharmacology*. Vols. I-XIII. Pergamon Press, Oxford, New York.
- Muraleedharan K. 1997. *Recent Advances in Insect Endocrinology*. Association for Advancement of Entomology, Trivandrum, Kerala.
- Rockstein, M. 1978. *Biochemistry of Insects*, Academic Press.

- Simpson, SJ. 2007. *Advances in Insect Physiology*, Vol. 33, Academic Press (Elsevier), London, UK.

I. Course Title : Insect Ecology and Diversity

II. Course Code : ENT 603

III. Credit Hours : 3 (2+1)

IV. Aim of the course

To impart advanced practical knowledge of causal factors governing the distribution and abundance of insects and the evolution of ecological characteristics. Study insect-plant interactions; get acquainted with biodiversity and conservation.

V. Theory

Unit I

Characterization of distribution of insects- Indices of Dispersion, Taylor's Power law. Island Biogeography. Population dynamics- Life tables, Leslie Matrix, Stable age distribution, Population projections. Predator-Prey Models- Lotka-Volterra and Nicholson-Bailey Model.Crop Modeling- an introduction.

Unit II

Insect Plant Interactions. Fig-figwasp mutualism and a quantitative view of types of associations. Role of insects in the environment.Adaptations to terrestrial habitats. Evolution of insect diversity and role of phytophagy as an adaptive zone for increased diversity of insects. Evolution of resource harvesting organs, resilience of insect taxa and the sustenance of insect diversity- role of plants.Herbivory, pollination, predation, parasitism. Modes of insect-plant interaction, tri-trophic interactions. Evolution of herbivory, monophagy vs polyphagy.Role of plant secondary metabolites.Meaning of stress- plant stress and herbivory.Consequences of herbivory to plant fitness and response to stress.Constitutive and induced plant defenses.Host seeking behavior of parasitoids.

Unit III

Biodiversity and Conservation- RET species, Ecological Indicators. Principles of Population genetics, Hardy Weinberg Law, Computation of Allelic and Phenotypic frequencies, Fitness under selection, Rates of Evolution under selection. Foraging Ecology- Optimal foraging theory, Marginal Value Theorem, and Patch departure rules, central place foraging, Mean-variance relationship and foraging by pollinators, Nutritional Ecology.

Unit IV

Reproductive ecology- Sexual selection, Mating systems, Reproductive strategies – timing, egg number, reproductive effort, sibling rivalry and parent- offspring conflict. Agro-ecological vs Natural Ecosystems – Characterisation, Pest Control as applied ecology- case studies.

VI. Practical

Methods of data collection under field conditions; Assessment of distribution parameters, Taylor's power law, Iwao's patchiness index, Index of Dispersion,etc.; Calculation of sample sizes by different methods; Fitting Poisson and Negative Binomial distributions and working out the data transformation methods; Hardy-Weinberg Law, Computation of Allelic and Phenotypic Frequencies – Calculation of changes under selection, Demonstration of genetic drift; Assessment of Patch Departure rules. Assessment of Resource size by female insects using a suitable insect model, fruit flies/ *Goniozus*/ Female Bruchids, etc.;A test of reproductive effort and fitness; Construction of Lifetables and application of Leslie Matrix– population projections, Stable age distribution; Exercises in development of Algorithms for crop modeling;

VII. Learning outcome

The scholar is expected to develop expertise in methods of data collection for insect populationstudies, data transformation for analyses, diversity estimates, assessing distribution parameters, study the impact of abiotic and biotic factors on the distribution and abundance of insects.

Should gain significant knowledge on construction of life tables and their analyses, assessment of resource size by female insects, reproductive effort and fitness.

VIII. Suggested Reading

- Barbosa P and Letourneau DK. (Eds.). 1988. *Novel Aspects of Insect-Plant Interactions*. Wiley, London.
- Elizabeth BA and Chapman RF. 1994.*Host-Plant Selection by Phytophagous Insects.*Chapman and Hall, NewYork.
- Freeman S and Herron JC.1998.*Evolutionary Analysis*. Prentice Hall, New Delhi.
- Gotelli NJ and Ellison AM. 2004. *A Primer of Ecological Statistics*. Sinauer

Associates, Sunderland, MA.

- Gotelli NJ. 2001. *A Primer of Ecology*. 3rd Ed., Sinauer Associates, Sunderland, MA, USA. Krebs C. 1998. *Ecological Methodology*.2nd Ed. Benjamin-Cummings Publ. Co., New York.
- Krebs CJ. 2001 *Ecology: The Experimental Analysis of Distribution and Abundance*. 5th Ed.Benjamin-Cummings Publ. Co., New York.
- Magurran AE. 1988. *Ecological Diversity and its Measurement*.Princeton University Press, Princeton.
- Real LA and Brown JH. (Eds.). 1991. *Foundations of Ecology: Classic Papers with Commentaries.*University of Chicago Press, USA.
- Southwood TRE and Henderson PA. 2000. *Ecological Methods.* 3rd Ed. Wiley Blackwell, London.
- Strong DR, Lawton JH and Southwood R. 1984.*Insects on Plants: Community Patterns and Mechanism*. Harward University Press, Harward.
- Wratten SD and Fry GLA. 1980. *Field and Laboratory Exercises in Ecology*. Arnold Publ., London.

I. Course Title : Insect Behaviour

II. Course Code : ENT 604

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To acquaint the students with a thorough understanding of how natural selection has led to various survival strategies manifested as behavior in insects.

V. Theory

Unit I

Defining Behaviour- Concept of umwelt, instinct, fixed action patterns, imprinting, complex behavior, inducted behavior, learnt behavior and motivation. History of Ethology- development of behaviorism and ethology, contribution of Darwin, Frisch, Tinbergen and Lorenz; Studying behavior- Proximate and Ultimate approaches, behavioural traits under natural selection, genetic control of behavior and behavioural polymorphism.

Unit II

Orientation- Forms of primary and secondary orientation including taxes and kinesis; Communication- primary and secondary orientation, responses to environmental stimuli, role of visual, olfactory and auditory signals in inter- and intra-specific communication, use of signals in defense, mimicry, polyphenism; evolution of signals.

Unit III

Reproductive behavior- mate finding, courtship, territoriality, parental care, parental investment, sexual selection and evolution of sex ratios; Social behavior-kin selection, parental manipulation and mutualism; Self organization and insect behavior.

Unit IV

Foraging- Role of different signals in host searching (plant and insects) and host acceptance, ovipositional behavior, pollination behavior, co-evolution of plants and insect pollinators. Behaviour in IPM- Concept of super-normal stimuli and behavioural manipulation as potential tool in pest management, use of semio-chemicals, auditory stimuli and visual signals in pest management.

VI. Practical

Quantitative methods in sampling behavior; Training bees to artificial feeders; Sensory adaptation and habituation in a fly or butterfly model, physical cues used in host selection in a phytophagous insect, chemical and odour cues in host selection in phytophagous insect (DBM or gram pod borer), colour discrimination in honey bee or butterfly model, learning and memory in bees, role of self-organization in resource tracking by honeybees; Evaluation of different types of traps against fruit flies with respect to signals; Use of honey bees /*Helicoverpa armigera* to understand behavioural polymorphism with respect to learning and response to pheromone mixtures, respectively.

VII. Learning outcome

Scholarsareexpectedtobewellversedwiththebehaviorandorientationofinsects towards exploitation as a tool in IPM.

VIII. SuggestedReading

- Ananthkrishnan TN. (Ed.). 1994. *Functional Dynamics of Phytophagous Insects*. Oxford and IBH, New Delhi.
- Awasthi VB. 2001. *Principles of Insect Behaviour*. Scientific Publ., Jodhpur.
- Bernays EA and Chapman RF. 1994.*Host-Plant Selection by Phytophagous Insects*. Chapman and Hall,London.
- Brown LB. 1999. *The Experimental Analysis of Insect Behaviour.*Springer, Berlin.

- Krebs JR and Davies NB. 1993. *An Introduction to Behavioural Ecology.* 3rd Ed. Chapman and Hall, London.
- Manning A and Dawkins MS.1992. *AnIntroduction to AnimalBehaviour*. CambridgeUniversity Press,USA.
- Mathews RW and Mathews JR. 1978.*Insect Behaviour*.A Wiley-InterScience Publ. John Wiley and Sons, New York.

I. Course Title : Bio-inputs for Pest Management
II. Course Code : ENT 605
III. Credit Hours : 3 (2+1)

IV. Aim of the course

To appraise the students with advanced techniques in handling of different bio- agents, modern methods of biological control and scope in cropping system-based pest management in agro-ecosystems.

V. Theory

UnitI

Scope of classical biological control and augmentative bio-control; introduction and handling of natural enemies; nutrition of entomophagous insects and their hosts.

Unit II

Bio-inputs: mass production of bio-pesticides, mass culturing techniques of bio- agents, insectary facilities and equipments, basic standards of insectary, viable mass-production unit, designs, precautions, good insectary practices.

Unit III

Colonization, techniques of release of natural enemies, recovery evaluation, conservation and augmentation of natural enemies, survivorship analysis and ecological manipulations, large-scale production of bio-control agents. Scope of endophytes and endosymbionts in microbial pest management

Unit IV

Scope of genetically engineered microbes and parasitoids in biological control, genetics of ideal traits in bio-control agents for introgressing and for progeny selections, breeding techniques of bio-control agents.

VI. Practical

Massrearingandreleaseofsomecommonlyoccurringindigenousnaturalenemi es; Assessment of role of natural enemies in reducing pest populations; Testing side effects of pesticides on natural enemies; Effect of semio-chemicals on natural enemies, breeding of various bio-control agents, performance of efficiency analyses on target pests; Project document preparation for establishing a viable mass-production unit/ insectary; Working out feeding potential of predators. Visit to industrial biopesticide production units

VII. Learning outcome

Scholars are expected to learn the mass multiplication techniques of the more common and economically feasible natural enemies to be exploitedunder IPM programmes.

They should be able to guide entrepreneurs for establishing a viable mass- production unit/insectary.

VIII. Suggested Reading

- Burges HD and Hussey NW. (Eds.). 1971. *Microbial Control of Insects and Mites.* Academic Press, London.
- Coppel HC and James WM. 1977.*Biological Insect Pest Suppression.* Springer Verlag, Berlin.
- De Bach P. 1964. *Biological Control of Insect Pests and Weeds.*Chapman and Hall, London.
- Dhaliwal,GS and KoulO. 2007. *Biopesticides and PestManagement*. KalyaniPublishers, New Delhi.
- Gerson H and Smiley RL.1990. *Acarine Biocontrol Agents – An Illustrated Key and Manual*.Chapman and Hall, New York.
- Huffakar CB and Messenger PS. 1976.*Theory and Practices of Biological Control.*Academic Press, London.

I.	**Course Title**	**: Insecticide Toxicology and Residues**
II.	**Course Code**	**: ENT 606**
III.	**Credit Hours**	**: 3 (2+1)**

IV. Aim of the course

To acquaint the students with the latest advancements in the field of insecticide toxicology, biochemical and physiological target sites of insecticides, and pesticide resistance mechanisms in insects.

V. Theory

Unit I

Penetration and distribution of insecticides in insect systems; insecticide selectivity; factors affecting toxicity of insecticides. Modes of action of newer insecticide molecules; developments in bio-rational approaches; SPLAT; RNAi technology for pest management.

Unit II

Biochemical and physiological target sites of insecticides in insects; developments in biorationals, biopesticides and newer molecules; their modes of action and structural – activity relationships; advances in metabolismof insecticides.

Unit III

Joint action of insecticides; activation, synergism and potentiation.

Unit IV

Problems associated with pesticide use in agriculture: pesticide resistance; resistance mechanisms and resistant management strategies; pest resurgence and outbreaks; persistence and pollution; health hazards and other sideeffects.

Unit V

Estimation of insecticidal residues- sampling, extraction, clean-up and estimation by various methods; quantification and Confirmation of pesticide residues; maximum residue limits (MRLs) and their fixation; bound and conjugated residues, effect on soil fertility; insecticide laws and standards, and good agricultural practices.

VI. Practical

Residue sampling, extraction, clean-up and estimation of insecticide residues by various methods; Calculations and interpretation of data; Biochemical and biological techniques for detection of insecticide resistance in insects; Preparation of EC formulation using neem oil.

VII. Learning outcome

Scholars are expected to be well versed with the latest technologies of bioassays, insecticide/ pesticide residue analysis and solving problems associated with insect resistance to insecticides.

VIII. Suggested Reading

- Busvine JR. 1971.*A Critical Review on the Techniques for Testing*

Insecticides.CABI, London.

- Dhaliwal GS and Koul O. 2007.*Biopesticides and Pest Management*. Kalyani Publishers, New Delhi.
- Hayes WJ and Laws ER. 1991. *Handbook of Pesticide Toxicology*. Academic Press, New York.
- Ishaaya I and Degheele (Eds.). 1998. *Insecticides with Novel Modes of Action.* Narosa Publ.House, New Delhi.
- Kranthi K.R. 2005. *Insecticide Resistance*: *Monitoring, Mechanisms and Management Manual*. CICR, Nagpur.
- Latrou K. and Gill S.S. 2004. *Comprehensive Molecular Insect Science Vol. 5 and 6*. Elsevier
- Matsumura F. 1985. *Toxicology of Insecticides.*Plenum Press, New York.
- Mohan M., Venkatesan T., Sivakumar G., Yandigeri M.S. and Verghese A. 2016. *Fighting Pesticide Resistance in Arthropods*. ICAR-NBAIR, Bengaluru.
- O' Brien RD. 1974.*Insecticides Action and Metabolism.*Academic Press, New York.
- Prakash A and Rao J. 1997.*Botanical Pesticides in Agriculture.*Lewis Publ., New York.
- Perry AS, Yamamoto I, Ishaaya I and Perry R. 1998.*Insecticides in Agriculture and Environment.*Narosa Publ. House, New Delhi.
- Roush R.T. 1990. *Pesticide Resistance in Arthropods*. Chapman and Hall, New York.
- Sharma K.K. 2013. *Pesticide Residue Analysis Manual.* Indian Council of Agricultural Research.
- Whalon M.E., Mota-Sanchez D. and Hollingworth R.M. 2008. *Global Pesticide Resistance in Arthropods*. CABI, Oxfordshire.
- Yu S.J. 2014. *The Toxicology and Biochemistry of Insecticides*. CRC Press, Boca Raton

I. Course Title : Plant Resistance to Insects

II. Course Code : ENT 607

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To familiarize the students with recent advances in resistance of plants to insects and acquaint with the techniques for assessment and evaluation of resistance in crop plants.

V. **Theory**

Unit I

Importance of plant resistance, historical perspective, desirable morphological, anatomical and biochemical adaptations of resistance; assembly of plant species – gene pool; insect sources – behaviour in relation to host plant factors.

Unit II

Physical and chemical environment conferring resistance in plants, role of trypsin inhibitors and protease inhibitors in plant resistance; biochemistry of induced resistance – signal transduction pathways, methyl jasmonate pathways, polyphenol oxidase pathways, salicylic acid pathways; effects of induced resistance; exogenous application of elicitors.

Unit III

Biotechnological approaches in host plant resistance- genetic manipulation of secondary plant substances; incorporation of resistant gene in crop varieties; marker- aided selection in resistance breeding.

Unit IV

Estimation of plant resistance based on plant damage- screening and damage rating; evaluation based on insect responses; techniques and determination of categories of plant resistance; breakdown of resistance in crop varieties.

VI. **Practical**

Understanding mechanisms of resistance for orientation, feeding, oviposition, etc., allelochemical bases of insect resistance; Macroculturing of test insects like aphids, leaf/ plant hoppers, mites and stored grain pests; Field screening- microplot techniques, infester row technique, spreader row technique and plant nurseries; Determination of anti xenosis index, antibiosis index, tolerance index, plant resistance index.

VII. **Learning outcome**

Scholars are expected to identify sources of resistance in different crops and varieties; their utilization in resistance breeding programmes involving screening techniques for specific pests.

VIII. **Suggested Reading**

- Panda N. 1979.*Principles of Host Plant Resistance toInsects*.Allenheld, Osum and Co., New York.
- Rosenthal GA and Janzen DH. (Eds.). 1979. *Herbivores – their*

Interactions with Secondary Plant Metabolites. Vol.I,II. Academic Press, NewYork.

- Sadasivam S and Thayumanavan B. 2003.*Molecular Host Plant Resistance to Pests*. Marcel Dekker, New York.
- Smith CM, Khan ZR and Pathak MD. 1994. *Techniques for Evaluating Insect Resistance in Crop Plants*. CRC Press, Boca Raton, Florida.

I. Course Title : Acarology

II. Course Code : ENT 608

III. Credit Hours : 2 (1+1)

IV. Aim of the course

To acquire a good working knowledge of identification of economically important groups of mites up to the species level, a detailed understanding of the newer acaricide molecules and utilization of predators.

V. Theory

Unit I

Comparative morphology of Acari, phylogeny of higher categories in mites, knowledge of commonly occurring orders and families of Acari in India.Diagnostic characteristics of commonly occurring species from families Tetranychidae, Tenuipalpidae, Eriophyidae, Tarsonemidae, Phytoseiidae, Bdellidae, Cunaxidae, Stigmaeidae, Pymotidae, Cheyletidae, Acaridae, Pyroglyphidae, Orthogalumnidae, Argasidae, Ixodidae, Sarcoptidae. Soil mites in India.

Unit II

Management of economical important species of mites in agriculture, veterinary and public health; storage acarology.

Unit III

Mites as vectors of plant pathogens; mode of action, structure-activity relationships of different groups of acaricides; problem of pesticide resistance in mites, resurgence of mites.

Unit IV

Predatory mites, their mass production and utilization in managing mite pests, acaropathogenic fungi- identification, isolation and utilization.

VI. Practical

Identification of commonly occurring mites up to species, preparation of keys for identification; Collection of specific groups of mites and preparing the identification keys; Rearing phytoseiid mites and studying the suppression of spider mites;Management of mite pests of crops using acaricides, phytoseiid predators, fungal pathogens etc.

VII. Learning outcome

Scholars should be able to identify major mite pests, their management and predatory mites that can be used in biological control.

They are also expected to learn the rearing techniques of predatory Phytoseiid mites.

VIII. Suggested Reading

- Evans GO.1992. *Principles of Acarology*.CABI, London.
- Gerson H and Smiley RL.1990. *Acarine Bio-control Agents- An Illustrated Key and Manual*.Chapman and Hall, New York.
- Gupta SK. 1985. *Handbook of Plant Mites of India.* Zoological Survey of India, Calcutta.
- Krantz GW. 1970. *A Manual of Acarology.* Oregon State University Book Stores, Corvallis,Oregon.
- Sadana GL. 1997. *False Spider Mites Infesting Crops in India*.Kalyani Publ. House, New Delhi.

I. Course Title : Molecular Entomology
II. Course Code : ENT 609
III. Credit Hours : 2 (1+1)
IV. Aim of the course

To familiarize the students with DNA recombinant technology, marker genes, transgenic plants, and biotechnological advances in sericulture and apiculture.

V. Theory

Unit I

Introduction to molecular biology; techniques used in molecular biology.

Unit II

DNA and RNA structure- transcription and translation mechanisms. DNA recombinant technology, identification of genes/ nucleotide sequences for characters of interest. Genes of interest in entomological research- marker genes for sex identification, neuropeptides, JH esterase, St toxins and venoms, chitinase, CPTI; lectins and proteases.

Unit III

Transgenic plants for pest resistance and diseases. introduction of genes for pest suppression Resistance management strategies in transgenic crops.. Molecular biology of baculoviruses, genetic engineering in baculoviruses Bt and entomopathogenic fungi

Unit IV

Insect gene transformation; biotechnology in relation to silkworms and honey bees; Genetic improvement of natural enemies. Cell lines; Sf transgenic technology and implications

Unit V

Insect immune systems in comparison to vertebrates; molecular basis of metamorphosis; Molecular basis of insecticide resistance. DNA-based diagnostics :DNA finger printing for taxonomy and phylogeny.

VI. Practical

Isolation of DNA/RNA; Purity determinations, purification of total DNA from animal tissues; Base pair estimation; Agarose gelelectrophoresis; Quantitative enzyme profile of alimentary canal; Restriction mapping of DNA;Demonstration of PCR, RFLP and RAPD techniques.

VII. Learning outcome

The scholars are expected to have mastered the molecular techniques applicable in entomological research like isolation of insect DNA, purification, DNA barcoding and utilizing these techniques in molecular systematics and biological controlaspects.

VIII. Suggested Reading

- Bhattacharya TK, Kumar P and Sharma A. 2007.*AnimalBiotechnology*.1st Ed., Kalyani Publication, New Delhi.
- Hagedon HH, Hilderbrand JG, Kidwell MG and Law JH. 1990. *Molecular Insect Science.* Plenum Press, New York.
- Hoy MA. 2003. *Insect Molecular Genetics: An Introduction to Principles and Applications*. 2nd Ed. Academic Press, New York.
- Oakeshott J and Whitten MA. 1994. *Molecular Approaches to Fundamental and Applied Entomology.* Springer Verlag.
- Rechcigl JE and Rechcigl NA. 1998. *Biological and Biotechnological Control of Insect Pests.*Lewis Publ., North Carolina.
- Roy U and Saxena V. 2007.*A Hand Book of Genetic Engineering*. 1st Ed., Kalyani Publishers, New Delhi.
- Singh BD. 2008. *Biotechnology* (*Expanding Horizons*). Kalyani Publishers, New Delhi. Singh P. 2007.*Introductory to Biotechnology*. 2nd Ed. Kalyani Publishers, New Delhi.

I. Course Title : Integrated Pest Management

II. Course Code : ENT610

III. Credit Hours : 2 (2+0)

IV. Aim of the course

To acquaint the students with recent concepts of integrated pest management; surveillance and data base management; successful national and international case histories of integrated pest management, non- conventional tools in pest management.

V. Theory

Unit I

Principles of sampling and surveillance, database management and computer programming; simulation techniques, system analysis and modeling.

Unit II

Study of case histories of national and international programmes, their implementation, adoption and criticism; global trade and risk of invasive pests; updating knowledge on insect outbreaks and their management.

Unit III

Genetic engineering and new technologies- their progress and limitations in IPM programmes, deployment of benevolent alien genes for pest management-case studies; scope and limitations of bio-intensive and ecological based IPM programmes; application of IPM to farmers' real time situation.

Unit IV

Challenges, needs and future outlook; dynamism of IPM under changing cropping systems and climate; insect pest management under protected cultivation; strategies for pesticide resistance management.

VI. Learning outcome

Having gained sufficient experience in advanced studies of IPM the scholars should be able to independently frame IPM schedules for major crops/ cropping ecosystems (cereal/ pulse crop/ oilseed crop based/ vegetable crop based agro-ecosystems).

VII. Suggested Reading

- Dhaliwal GS and Arora R. 2003.*Integrated Pest Management – Concepts and Approaches*.Kalyani Publishers, New Delhi.
- Dhaliwal GS, Singh R and Chhillar BS. 2006. *Essentials of Agricultural Entomology*. Kalyani Publishers, New Delhi.
- Flint MC and Bosch RV. 1981. *Introduction to Integrated Pest Management.* Springer, Berlin.
- Koul O and Cuperus GW.2007. *Ecologically Based Integrated PestManagement.* CABI,London.
- Koul O, Dhaliwal GS and Curperus GW.2004. *Integrated Pest Management–Potential,Constraints and Challenges*.CABI, London.
- Maredia KM, Dakouo D and Mota-Sanchez D. 2003.*Integrated Pest Management in the Global Arena*.CABI, London.
- Metcalf RL and Luckman WH. 1982.*Introduction to Insect Pest Management*.John Wiley and Sons, NewYork.
- Norris RF, Caswell-Chen EP and Kogan M. 2002.*Concepts in Integrated Pest Management*.Prentice Hall, New Delhi.
- Pedigo RL. 1996. *Entomology and Pest Management.* Prentice Hall, New Delhi.
- Subramanyam B and Hagstrum DW. 1995. *Integrated Management of Insects in Stored Products*.Marcel Dekker, New York.

PLANT PATHOLOGY

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

Course Code	Course Title	Credit Hours
PL PATH 501*	Mycology	2+1
PL PATH 502*	Plant Virology	2+1
PL PATH 503*	Plant Pathogenic Prokaryotes	2+1
PL PATH 504	Plant Nematology	2+1
PL PATH 505*	Principles of Plant Pathology	2+1
PL PATH 506*	Techniques in Detection and Diagnosis of Plant Diseases	0+2
PL PATH 507	Principles of Plant Disease Management	2+1
PL PATH 508	Epidemiology and Forecasting of Plant Diseases	1+0
PL PATH 509	Disease Resistance in Plants	2+0
PL PATH 510	Ecology of Soil-borne Plant Pathogens	1+1
PL PATH 511*	Chemicals and Botanicals in Plant Disease Management	2+1
PL PATH 512	Detection and Management of Seed Borne Pathogens	2+1
PL PATH 513*	Biological Control of Plant Pathogens	1+1
PL PATH 514	Integrated Disease Management	2+1
PL PATH 515	Diseases of Field and Medicinal Crops	2+1
PL PATH 516	Diseases of Fruits, Plantation and Ornamental Crops	2+1
PL PATH 517	Diseases of Vegetable and Spices Crops	2+1
PL PATH 518	Post Harvest Diseases	1+1
PL PATH 519	Plant Quarantine and Regulations	1+0
PL PATH 591	Master’s Seminar	0+1
PL PATH 599	Master’s Research	0+30

*Core Courses for Master’s

I. **Course Title : Mycology**

II. **Course Code : PL PATH 501**

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

IV. **Aim of the course**

To study the nomenclature, classification and characters of fungi.

V. **Theory**

Unit I

Introduction, definition of different terms, basic concepts. Importance of mycology in agriculture, relation of fungi to human affairs. History of mycology. Importance of culture collection and herbarium of fungi. Somatic characters and reproduction in fungi. Modern concept of nomenclature and classification, Classification of kingdom fungi: Stramenopila and Protists.

Unit II

The general characteristics of protists and life cycle in the Phyla Plasmodiophoromycota, Dictyosteliomycota, Acrasiomycota and Myxomycota. Kingdom Stramenopila: characters and life cycles of respective genera under Hypochytriomycota, Oomycota and Labyrinthulomycota.

Unit III

Kingdom fungi: General characters, ultrastructure and life cycle patterns in representative genera under Chytridiomycota, Zygomycota, Ascomycota; Archiascomycetes, Ascomycetous yeasts, Pyrenomycetes, Plectomycetes, Discomycetes, Loculoascomycetes, Erysiphales and anamorphs of ascomycetous fungi.

Unit IV

Basidiomycota; general characters, mode of reproduction, types of basidiocarps and economic importance of Hymenomycetes. Uridinales and Ustilaginales; variability, host specificity and life cycle pattern in rusts and smuts. Mitosporic fungi; status of asexual fungi, their teliomorphic relationships, Molecular characterization of plant pathogenic fungi.

VI. **Practical**

- Detailed comparative study of different groups of fungi;
- Collection of cultures and live specimens;
- Saccardoan classification and classification based on conidiogenesis;
- Vegetative structures and different types of fruiting bodies produced by slime molds,stramenopiles and true fungi;

- Myxomycotina: Fructification, plasmodiocarp, sporangia, plasmodium and aethalia. Oomycota;
- Somatic and reproductory structures of *Pythium*, *Phytophthora*, downy mildews and *Albugo*, Zygomycetes: Sexual and asexual structures of *Mucor*, *Rhizopus*, General characters of VAM fungi. Ascomycetes; fruiting structures, Erysiphales, and Eurotiales;
- General identification characters of Pyrenomycetes, Discomycetes, Loculo-ascomycetes and Laboulbenio-mycetes, Basidiomycetes; characters, ultrastructures and life cycle patterns in Ustilaginomycetes and Teliomycetes, Deuteromycetes;
- Characters of Hyphomycetes and Coelomycetes and their teliomorphic and anamorphic states, Collection, preservation, culturing and identification of plant parasitic fungi;
- Application of molecular approaches and techniques for identification of fungal pathogens.

VII. Suggested Reading

- Ainsworth GC, Sparrow FK and Susman HS. 1973. *The Fungi – An Advanced Treatise*. Vol. IV(A & B). Academic Press, New York.
- Alexopoulos CJ, Mims CW and Blackwell M.2000. *Introductory Mycology.* 5th Ed. John Wiley & Sons, New York.
- Maheshwari R. 2016. *Fungi: Experimental Methods in Biology* 2nd edn. CRC Press, US. Mehrotra RS and Arneja KR. 1990. *An Introductory Mycology*. Wiley Eastern, New Delhi. Sarbhoy AK. 2000. *Text book of Mycology*. ICAR, New Delhi.
- Singh RS. 1982. *Plant Pathogens – The Fungi*. Oxford & IBH, New Delhi.
- Webster J. 1980. *Introduction to Fungi*. 2nd Ed. Cambridge Univ. Press, Cambridge, New York.

I. Course Title : Plant Virology

II. Course Code : PL PATH 502

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with the structure, virus- vector relationship, biology and managementof plant viruses.

V. Theory

Unit I

History and economic significances of plant viruses. General and morphological characters, composition and structure of viruses. Myco-viruses, arbo and baculo viruses, satellite viruses, satellite RNAs, phages, viroids and prions**.** Origin and evolution of viruses and their nomenclature and classification.

Unit II

Genome organization, replication in selected groups of plant viruses and their movement in host. Response of the host to virus infection: biochemical, physiological, and symptomatical changes. Transmission of viruses and virus-vector relationship. Isolation and purification of viruses.

Unit III

Detection and identification of plant viruses by using protein and nucleic acid based diagnostic techniques. Natural (R-genes) and engineering resistance to plant viruses.

Unit IV

Virus epidemiology and ecology (spread of plant viruses in fields, host range and survival). Management of diseases caused by plant viruses.

VI. Practical

- Study of symptoms caused by plant viruses (followed by field visit);
- Isolation and biological purification of plant virus cultures;
- Bioassay of virus cultures on indicator plants and host differentials;
- Transmission of plant viruses (Mechanical, graft and vector and study of disease development);
- Plant virus purification (clarification, concentration, centrifugation, high resolution separation and analysis of virions), Electron microscopy for studying viral particlemorphology;
- Antisera production, Detection and diagnosis of plant viruses with serological (ELISA), nucleic acid (Non-PCR–LAMP, Later flow micro array and PCR based techniques);
- Exposure to basic bio-informatic tools for viral genome analysis and their utilization in developing detection protocols and population studies (BLASTn tool, Primer designing software, Bioedit tool, Claustal X/W, MEGA Software).

VII. Suggested Reading

- Bos L. 1964. *Symptoms of Virus Diseases in Plants*. Oxford & IBH., New Delhi.

- Brunt AA, Krabtree K, Dallwitz MJ, Gibbs AJ and Watson L. 1995. *Virus of Plants: Descriptions and Lists from VIDE Database*. CABI, Wallington.
- Gibbs A and Harrison B. 1976. *Plant Virology – The Principles*. Edward Arnold, London. Hull R. 2002. *Mathew's Plant Virology*. 4th Ed. Academic Press, New York.
- Noordam D. 1973. *Identification of Plant Viruses, Methods and Experiments*. Oxford & IBH, New Delhi.
- Wilson C. 2014. *Applied Plant Virology*. CABI Publishing England.

I. **Course Title : Plant Pathogenic Prokaryotes**

II. **Course Code : PL PATH 503**

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

IV. **Aim of the course**

To acquaint with plant pathogenic prokaryote (procarya) and their structure, nutritional requirements, survival and dissemination.

V. **Theory**

Unit I

Prokaryotic cell: History and development of Plant bacteriology, history of plant bacteriology in India. Evolution of prokaryotic life, Prokaryotic cytoskeletal proteins. Structure of bacterial cell. Structure and composition of gram negative and gram positive cell wall; synthesis of peptidoglycan; Surface proteins; Lipopolysaccaride structure; Membrane transport; fimbrae and pili (Type IV pili); Mechanism of flagellar rotatory motor and locomotion, and bacterial movement; Glycocalyx (S- layer; capsule); the bacterial chromosomes and plasmids; Operon and other structures in cytoplasm; Morphological feature of fastidious bacteria, spiroplasmas and Phytoplasmas.

Unit II

Growth and nutritional requirements. Infection mechanism, role of virulence factors in expression of symptoms. Survival and dispersal of phytopathogenic prokaryotes.

Unit III

Taxonomy of phytopathogenic prokarya: Taxonomic ranks hierarchy; Identification, Classification and nomenclature of bacteria, phytoplasma and spiroplasma. The codes of Nomenclature and characteristics. Biochemical and molecular characterization of phytopathogenic prokaryotes.

Unit IV

Variability among phytopathogenic prokarya: general mechanism of variability (mutation); specialized mechanisms of variability (sexual like process in bacteria- conjugation; transformation; transduction); and horizontal gene transfer.

Unit V

Bacteriophages, L form of bacteria, plasmids and bdellovibrios: Structure; Infection of host cells; phage multiplication cycle; Classification of phages, Use of phages in plant pathology/ bacteriology, Lysogenic conversion; H Plasmids and their types, plasmid borne phenotypes.Introduction to bacteriocins. Strategies for management of diseases caused by phytopathogenic prokaryotes.

VI. **Practical**

- Study of symptoms produced by phytopathogenic prokaryotes;
- Isolation, enumeration, purification, identification and host inoculation of phytopathogenic bacteria;
- Stains and staining methods;
- Biochemical and serological characterization;
- Isolation of genomic DNA plasmid;
- Use of antibacterial chemicals/ antibiotics;
- Isolation of fluorescent *Pseudomonas*;
- Preservation of bacterial cultures;
- Identification of prokaryotic organisms by using 16S rDNA, and other gene sequences;
- Diagnosis and management of important diseases caused by bacteria and mollicutes.

VII. **Suggested Reading**

- Goto M. 1990. *Fundamentals of Plant Bacteriology*. Academic Press, New York.
- Jayaraman J and Verma JP. 2002. *Fundamentals of Plant acteriology*. Kalyani Publishers, Ludhiana.
- Mount MS and Lacy GH. 1982. *Phytopathogenic Prokaryotes*. Vols. I, II Academic Press, New York.
- Salle AJ. 1979. *Fundamental Principles of Bacteriology 7th edn.*
- Verma JP, Varma A and Kumar D. (Eds). 1995. *Detection of Plant Pathogens and their Management*. Angkor Publ., New Delhi.

I. **Course Title : Plant Nematology**

II. **Course Code : PL PATH 504**

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

IV. Aim of the course

To project the importance of nematodes in agriculture and impart basic knowledgeon all aspects of plant nematology.

V. Theory

Unit I

Characteristics of Phylum Nematoda and its relationship with other related phyla, history and growth of Nematology; nematode habitats and diversity- plant, animal and human parasites; useful nematodes; economic importance of nematodes to agriculture, horticulture and forestry.

Unit II

Gross morphology of plant parasitic nematodes; broad classification, nematodebiology, physiology and ecology.

Unit III

Types of parasitism; nature of damage and general symptomatology; interaction ofplant-parasitic nematodes with other organisms.

Unit IV

Plant nematode relationships, cellular responses to infection by important phytonematodes; physiological specialization among phytonematodes.

Unit V

Principles and practices of nematode management; integrated nematode management.

Unit VI

Emerging nematode problems, Importance of nematodes in international trade andquarantine.

VI. Practical

- Studies on kinds of nematodes- free-living, animal, insect and plant parasites;
- Nematode extraction from soil;
- Extraction of migratory endoparasites, staining for sedentary endoparasites;
- Examination of different life stages of important plant parasitic nematodes, theirsymptoms and histopathology.

VII. Suggested Reading

- Dropkin VH. 1980. *An Introduction to Plant Nematology*. John Wiley & Sons, New York. Maggenti AR. 1981. *General Nematology.* Springer-Verlag, New York.

- Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed. CABI Publishing: Wallingford, UK.
- Perry RN, Moens M, and Starr JL. 2009. *Root-knot nematodes*, CABI Publishing: Wallingford, UK.
- Sikora RA, Coyne D, Hallman J and Timper P. 2018. *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture*.3rd edn. CABI Publishing, England.
- Thorne G. 1961. *Principles of Nematology*. McGraw Hill, New Delhi.
- Walia RK and Bajaj HK. 2003. *Text Book on Introductory Plant Nematology*. ICAR, New Delhi. Walia RK and Khan MR. 2018. *A Compendium of Nematode Diseases of Crop Plants*, ICAR-
- AICRP (Nematodes), IARI, New Delhi.

I. **Course Title : Principles of Plant Pathology**

II. **Course Code : PL PATH 505**

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

IV. **Aim of the course**

To introduce the subject of Plant Pathology, its concepts and principles.

V. **TheoryUnit I**

Importance, definitions and concepts of plant diseases, history and growth of plant pathology, biotic and abiotic causes of plant diseases.

Unit II

Growth, reproduction, survival and dispersal of important plant pathogens, role ofenvironment and host nutrition on disease development.

Unit III

Host parasite interaction, recognition concept and infection, symptomatology, disease development- role of enzymes, toxins, growth regulators; defense strategies- oxidative burst; Phenolics, Phytoalexins, PR proteins, Elicitors. Altered plant metabolism as affected by plant pathogens.

Unit IV

Genetics of resistance; ‘R’ genes; mechanism of genetic variation in pathogens; molecular basis for resistance; marker-assisted selection; genetic engineering for disease resistance.

VI. **Practical**

- Basic plant pathological techniques;
- Isolation, inoculation and purification of plant pathogens and proving Koch’spostulates;

- Techniques to study variability in different plant pathogens;
- Purification of enzymes, toxins and their bioassay;
- Estimation of growth regulators, phenols, phytoalexins in resistant and susceptibleplants.

VII. Suggested Reading

- Agrios GN. 2005. *Plant Pathology*. 5th Ed. Academic Press, New York.
- Heitefuss R and Williams PH. 1976. *Physiological Plant Pathology*. Springer Verlag, Berlin, New York.
- Mehrotra RS and Aggarwal A. 2003. *Plant Pathology*. 2nd Ed. Oxford & IBH, New Delhi. Singh RP. 2012. *Plant Pathology* 2nd edn. Kalyani Publishers, New Delhi.
- Singh RS. 2017. *Introduction to Principles of Plant Pathology*. 5th edn. MedTech, New Delhi. Singh DP and Singh A. 2007. *Disease and Insect Resistance in Plants.* Oxford & IBH, New Delhi.
- Upadhyay RK. and Mukherjee KG. 1997. *Toxins in Plant Disease Development and Evolving Biotechnology.* Oxford & IBH, New Delhi.

I. Course Title : Techniques in Detection and Diagnosis of Plant Diseases Course Code : PL PATH 506

II. Credit Hours : 0+2

III. Aim of the course

To impart training on various methods/ techniques/ instruments used in the studyof plant diseases/ pathogens.

IV. Practical

- Detection of plant pathogens 1. Based on visual symptoms, 2. Biochemical test 3.
- Using microscopic techniques, 4. Cultural studies; (use of selective media to isolate pathogens). 5. Biological assays (indicator hosts, differential hosts) 6. Serological assays 7. Nucleic acid based techniques (Non- PCR–LAMP, Later flow microarray and PCR based- multiplex, nested, qPCR, immune capture PCR, etc.);
- Phenotypic and genotypic tests for identification of plant pathogens;
- Molecular identification (16S rDNA and 16s-23S rDNA intergenic spacer region sequences-prokaryotic organisms; and eukaryotic organism by ITS region) and whole genome sequencing;

- Volatile compounds profiling by using GC-MS and LC-MS;
- FAME analysis, Fluorescence *in-situ* Hybridization (FISH), Flow Cytometry, Phage display technique, biosensors for detection of plant pathogens;
- Genotypic tools such as genome/ specific gene sequence homology comparison by BLAST (NCBI and EMBL) and electron microscopy techniques of plant virus detection and diagnosis.

V. Suggested Reading

- Baudoin ABAM, Hooper GR, Mathre DE and Carroll RB. 1990. *Laboratory Exercises in Plant Pathology: An Instructional Kit*. Scientific Publ., Jodhpur.
- Dhingra OD and Sinclair JB. 1986. *Basic Plant Pathology Methods*. CRC Press, London, Tokyo.
- Fox RTV. 1993. *Principles of Diagnostic Techniques in Plant Pathology,* CABI Wallington.
- Forster D and Taylor SC. 1998. *Plant Virology Protocols: From Virus Isolation to Transgenic*
- *Resistance*. *Methods in Molecular Biology*. Humana Press, Totowa, New Jersey.
- Mathews REF. 1993. *Diagnosis of Plant Virus Diseases*. CRC Press, Boca Raton, Tokyo.
- Matthews REF. 1993. *Diagnosis of Plant Virus Diseases*. CRC Press, Florida.
- Noordam D. 1973. *Identification of Plant Viruses, Methods and Experiments*. Cent. Agic. Pub. Doc. Wageningen.
- Pathak VN. 1984. *Laboratory Manual of Plant Pathology*. Oxford & IBH, New Delhi.
- Trigiano RN, Windham MT and Windham AS. 2004. *Plant Pathology-Concepts and Laboratory Exercises*. CRC Press, Florida.
- Chakravarti BP. 2005. *Methods of Bacterial Plant Pathology*. Agrotech, Udaipur.

I. **Course Title : Principles of Plant Disease Management**
II. **Course Code : PL PATH 507**
III. **Credit Hours : 2+1**
IV. **Aim of the course**

To acquaint with different strategies for management of plant diseases.

V. **Theory**

Unit I

Principles of plant disease management by cultural, physical, biological, chemical, organic amendments and botanicals methods of plant disease control, integrated control measures of plant diseases. Disease resistance and molecular approach for disease management.

Unit II

History of fungicides, bactericides, antibiotics, concepts of pathogen, immobilization, chemical protection and chemotherapy, nature, properties and mode of action of antifungal, antibacterial and antiviral chemicals. Label claim of fungicides.

Unit III

Application of chemicals on foliage, seed and soil, role of stickers, spreaders and other adjuvants, health *vis-a-vis* environmental hazards, residual effects and safety measures

VI. **Practical**

- Phytopathometry;
- Methods of *in-vitro* evaluation of chemicals, antibiotics, bio agents against plantpathogens;
- Field evaluation of chemicals, antibiotics, bio agents against plant pathogens;
- Soil solarisation, methods of soil fumigation under protected cultivation;
- Methods of application of chemicals and bio control agents;
- ED and MIC values, study of structural details of sprayers and dusters;
- Artificial epiphytotic and screening of resistance.

VII. **Suggested Reading**

- Fry WE. 1982. *Principles of Plant Disease Management.* Academic

Press, New York.

- Hewitt HG. 1998. *Fungicides in Crop Protection*. CABI, Wallington. Marsh RW. 1972. Systemic Fungicides. Longman, New York.
- Nene YL and Thapliyal PN. 1993. *Fungicides in Plant Disease Control*. Oxford & IBH, NewDelhi.
- Palti J. 1981. *Cultural Practices and Infectious Crop Diseases*. Springer Verlag, New York.
- Vyas SC. 1993 *Handbook of Systemic Fungicides*. Vols. I-III. Tata McGraw Hill, New Delhi.
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I. **Course Title : Epidemiology and Forecasting of Plant Diseases**

II. **Course Code : PL PATH 508**

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

IV. **Aim of the course**

To acquaint with the principles of epidemiology and its application in diseaseforecasting**.**

V. **Theory**

Unit I

Epidemic concepts, simple interest and compound interest disease, historical development. Elements of epidemics and their interaction.Structures and patterns of epidemics. Modelling, system approaches and expert systems in plant pathology.

Unit II

Genetics of epidemics. Models for development of plant disease epidemics. Common and natural logarithms, function fitting, area under disease progress curve and correction factors, inoculum dynamics. Population biology of pathogens, temporal and spatial variability in plant pathogens.

Unit III

Epidemiological basis of disease management. Survey, surveillance and vigilance. Remote sensing techniques and image analysis. Crop loss assessment.

Unit IV

Principles and pre-requisites of forecasting, systems and factors affecting various components of forecasting, some early forecasting and procedures based on weather and inoculum potential, modelling disease growth and disease prediction. Salient features of important forecasting models.

VI. **Suggested Reading**

- Campbell CL and Madden LV. 1990. *Introduction to Plant Disease*

Epidemiology. John Wiley & Sons, New York

- Cooke B, Jones DM and Gereth KB. 2018 *The Epidemiology of Plant Diseases*. Springer Publications.
- Cowling EB and Horsefall JG. 1978. *Plant Disease*. Vol. II. Academic Press, New York. Laurence VM, Gareth H and Frame Van den Bosch (Eds.). *The Study of Plant Disease Epidemics*.APS, St. Paul, Minnesota.
- Nagarajan S and Murlidharan K. 1995. *Dynamics of Plant Diseases*. Allied Publ., New Delhi. Thresh JM. 2006. *Plant Virus Epidemiology*. Advances in Virus Research 67, Academic Press,New York.
- Van der Plank JE. 1963. *Plant Diseases Epidemics and Control*. Academic Press, New York.
- Zadoks JC and Schein RD. 1979. *Epidemiology and Plant Disease Management*. Oxford Univ. Press, London.

I. Course Title : Disease Resistance in Plants

II. Course Code : PL PATH 509

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint with the disease resistance mechanisms.

V. Theory

Unit I

Introduction and historical development, dynamics of pathogenicity, process of infection, variability in plant pathogens, gene centres as sources of resistance, disease resistance terminologies. Disease escape,non-host resistance and disease tolerance.

Unit II

Genetic basis of disease resistance, types of resistance, identification of physiologicalraces of pathogen, disease progression in relation to resistance, stabilizing selection pressure in plant pathogens.

Unit III

Host defence system, morphological and anatomical resistance, pre-formed chemicals in host defence, post infectional chemicals in host defence, phytoalexins,hypersensitivity and its mechanisms. Genetic basis of relationships between pathogen and host, Gene-for-gene concept, protein-for- protein and immunization basis, management of resistance genes. Strategies for gene deployment.

VI. **Suggested Reading**

- Deverall BJ. 1977. *Defence Mechanisms in Plants*. Cambridge Univ. Press, Cambridge, New York.
- Mills Dallice *et al.*1996. *Molecular Aspects of Pathogenicity and Resistance: Requirement for Signal Transduction.* APS, St Paul, Minnesota.
- Parker J. 2008. *Molecular Aspects of Plant Diseases Resistance.*Blackwell Publ.
- Robinson RA. 1976. *Plant Pathosystems*. Springer Verlag, New York.
- Singh BD. 2005. *Plant Breeding – Principles and Methods*. 7th Ed. Kalyani Publishers,
- Ludhiana Van der Plank JE. 1975. *Principles of Plant Infection*. Academic Press, New York.
- Van der Plank JE. 1978. *Genetic and Molecular Basis of Plant Pathogenesis*. Springer Verlag. New York.
- Van der Plank JE. 1982. *Host Pathogen Interactions in Plant Disease*. Academic Press, New York.
- Van der Plank JE. 1984. *Disease Resistance in Plants*. Academic Press, New York.

I. **Course Title : Ecology of Soil Borne Plant Pathogens**

II. **Course Code : PL PATH 510**

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

IV. **Aim of the course**

To provide knowledge on soil-plant disease relationship.

V. **Theory**

Unit I

Soil as an environment for plant pathogens, nature and importance of rhizosphere and rhizoplane, host exudates, soil and root inhabiting fungi. Interaction of microorganisms.

Unit II

Types of biocontrol agents. Inoculum potential and density in relation to host and soil variables, competition, predation, antibiosis and fungistasis. Conducive and suppressive soils.

Unit III

Biological control- concepts and potentialities for managing soil borne pathogens. Potential of *Trichoderma* and fluorescent *Pseudomonas* in managing plant diseases.

VI. **Practical**

- Quantification of rhizosphere and rhizoplane microflora with special emphasis onpathogens;
- Pathogenicity test by soil and root inoculation techniques, correlation between inoculum density of test pathogens and disease incidence, demonstration of fungistasis in natural soils;
- Suppression of test soil-borne pathogens by antagonistic microorganisms;
- Isolation and identification of different biocontrol agents;
- Study of various plant morphological structures associated with resistance, testing the effect of root exudates and extracts on spore germination and growth of plant pathogens;
- Estimating the phenolic substances, total reducing sugars in susceptible andresistant plants;
- Estimating the rhizosphere and root tissue population of microorganisms (pathogens) in plants.

VII. **Suggested Reading**

- Baker KF and Snyder WC. 1965. *Ecology of Soil-borne Plant Pathogens*. John Wiley, New York.
- Cook RJ and Baker KF. 1983. *The Nature and Practice of Biological Control of Plant Pathogens*. APS, St Paul, Minnesota.
- Garret SD. 1970. *Pathogenic Root-infecting Fungi*. Cambridge Univ. Press,Cambridge, New York.
- Hillocks RJ and Waller JM. 1997. *Soil-borne Diseases of Tropical Crops*. CABI, Wallington. Mondia JL and Timper P 2016. Interactions of microfungi and plant parasitic nematodes. In: *Biology of Microfungi* (De-Wei-Lei Ed.). Springer Publications
- Parker CA, Rovira AD, Moore KJ and Wong PTN. (Eds). 1983. *Ecology and Management of Soil-borne Plant Pathogens*. APS, St. Paul, Minnesota.

I. **Course Title** : **Chemicals and Botanicals in Plant Disease Management**

II. **Course Code** : **PL PATH 511**

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

IV. **Aim of the course**

To provide knowledge on the concepts, principles and judicious use of chemicalsand botanicals in plant disease management**.**

V. **Theory**

Unit I

History and development of chemicals; definition of pesticides and related terms;advantages and disadvantages of chemicals and botanicals.

Unit II

Classification of chemicals used in plant disease management and their characteristics.

Unit III

Chemicals in plant disease control, viz., fungicides, bactericides, nematicides,antiviral chemicals and botanicals. Issues related to label claim.

Unit IV

Formulations, mode of action and application of different fungicides; chemotherapyand phytotoxicity of fungicides.

Unit V

Handling, storage and precautions to be taken while using fungicides; compatibility with other agrochemicals, persistence, cost-benefit ratio, factor affecting fungicides. New generation fungicides and composite formulations of pesticides.

Unit VI

Efficacy of different botanicals used and their mode of action. Important botanicals used against diseases. General account of plant protection appliances; environmental pollution, residues and health hazards, fungicidal resistance in plant pathogensand its management.

VI. **Practicals**

- Acquaintance with formulation of different fungicides and plant protection appliances;
- Formulation of fungicides, bactericides and nematicides;
- *In-vitro* evaluation techniques, preparation of different concentrations of chemicals including botanical pesticides against pathogens;
- Persistence, compatibility with other agro-chemicals;
- Detection of naturally occurring fungicide resistant mutants of pathogen;
- Methods of application of chemicals.

VII. **Suggested Reading**

- Bindra OS and Singh H. 1977. *Pesticides – And Application Equipment*. Oxford & IBH, New Delhi.
- Nene YL and Thapliyal PN. 1993. *Fungicides in Plant Disease Control.* 3rd edn. Oxford & IBH, New Delhi.
- Torgeson DC. (Ed.). 1969. *Fungicides.* Vol. II. An Advanced Treatise. Academic Press, New York.
- Vyas SC. 1993. *Handbook of Systemic Fungicides*. Vols. I-III. Tata McGraw Hill, New Delhi.

I. **Course Title : Detection and Management of Seed Borne Pathogens**

II. **Course Code : PL PATH 512**

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

IV. **Aim of the course**

To acquaint with seed-borne diseases, their nature, detection, transmission, epidemiology, impacts/ losses and management.

V. **Theory**

Unit I

History and economic importance of seed pathology in seed industry, plant quarantine and SPS under WTO. Morphology and anatomy of typical monocotyledonous and dicotyledonous infected seeds.

Unit II

Recent advances in the establishment and subsequent cause of disease development in seed and seedling. Localization and mechanism of seed transmission in relation to seed infection, seed to plant transmission of pathogens.

Unit III

Seed certification and tolerance limits, types of losses caused by seed-borne diseases in true and vegetatively propagated seeds, evolutionary adaptations of crop plants to defend seed invasion by seed-borne pathogens. Epidemiological factors influencing the transmission of seed-borne diseases, forecasting of epidemics through seed-borne infection.

Unit IV

Production of toxic metabolites affecting seed quality and its impact on human, animal and plant health, management of seed-borne pathogens/ diseases and procedure for healthy seed production. Seed health testing, methods for detecting microorganism.

VI. **Practical**

- Conventional and advanced techniques in the detection and identification of seed-borne fungi, bacteria and viruses;
- Relationship between seed-borne infection and expression of the disease in the field.

VII. **Suggested Reading**

- Agarwal VK and Sinclair JB. 1993. *Principles of Seed Pathology*. Vols. I & II, CBS Publ., New Delhi.
- Hutchins JD and Reeves JE. (Eds.). 1997. *Seed Health Testing: Progress Towards the 21st Century*. CABI, Wallington.
- Paul Neergaard. 1988. *Seed Pathology*. McMillan, London. Suryanarayana D. 1978. *Seed Pathology*. Vikash Publ., New Delhi.

I. **Course Title : Biological Control of Plant Pathogens**

II. **Course Code : PL PATH 513**

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

IV. **Aim of the course**

To study principles and application of ecofriendly and sustainable managementstrategies of plant diseases.

V. **TheoryUnit I**

Concept of biological control, definitions, importance, principles of plant disease management with bioagents, history of biological control, merits and demerits of biological control.

Unit II

Types of biological interactions, competition: mycoparasitism, exploitation for

hypovirulence, rhizosphere colonization, competitive saprophytic ability, antibiosis, induced resistance, mycorrhizal associations, operational mechanisms and its relevance in biological control.

Unit III

Factors governing biological control, role of physical environment, agroecosystem, operational mechanisms and cultural practices in biological control of pathogens, pathogens and antagonists and their relationship, biocontrol agents, comparative approaches to biological control of plant pathogens by resident and introduced antagonists, control of soil-borne and foliar diseases. Compatibility of bioagents with agrochemicals and other antagonistic microbes.

Unit IV

Commercial production of antagonists, their delivery systems, application and monitoring, biological control in IDM, IPM and organic farming system, biopesticides available in market. Quality control system of biocontrol agents.

VI. Practical

- Isolation, characterization and maintenance of antagonists, methods ofstudy of antagonism and antibiosis, application of antagonists against pathogen *in-vitro and in vivo* conditions;
- Preparation of different formulations of selected bioagents and their mass production;
- Quality parameters of biocontrol agents;
- One week exposure visit to commercial biocontrol agents production unit.

VII. Suggested Reading

- Campbell R. 1989. *Biological Control of Microbial Plant Pathogens*. Cambridge Univ. Press, Cambridge.
- Cook RJ and Baker KF. 1983. *Nature and Practice of Biological Control of Plant Pathogens*. APS, St. Paul, Minnesota.
- Fokkemma MJ. 1986. *Microbiology of the Phyllosphere*. Cambridge Univ. Press, Cambridge.
- Gnanamanickam SS (Eds). 2002. *Biological Control of Crop Diseases*. CRC Press, Florida. Heikki MT and Hokkanen James M. (Eds.). 1996. *Biological Control – Benefits and Risks*. Cambridge Univ. Press, Cambridge.
- Mukerji KG, Tewari JP, Arora DK and Saxena G. 1992. *Recent Developments in Biocontrol of Plant Diseases*. Aditya Books, New Delhi.

I. Course Title : Integrated Disease Management

II. Course Code : PL PATH 514

III. Credit Hours : 2+1

IV. Aim of the course

To emphasize the importance and the need of IDM in the management of diseasesof important crops.

V. TheoryUnit I

Introduction, definition, concept and tools of disease management, components of integrated disease management- their limitations and implications.

Unit II

Development of IDM-basic principles, biological, chemical and cultural disease management.

Unit III

IDM in important crops- rice, wheat, cotton, sugarcane, chickpea, rapeseed and mustard, pearl millet, pulses, vegetable crops, fruit, plantation and spice crops.

VI. **Practical**

- Application of physical, biological and cultural methods;
- Use of chemical and biocontrol agents, theircompatibility and integration in IDM.Demonstration of IDM and multiple disease management in crops of regional importance as project work.

VII. **Suggested Reading**

- Gupta VK and Sharma RC. (Eds). 1995. *Integrated DiseaseManagement and Plant Health*. Scientific Publ., Jodhpur.
- Mayee CD, Manoharachary C, Tilak KVBR, Mukadam DS and Deshpande Jayashree (Eds.). 2004. *Biotechnological Approaches for the Integrated Management of Crop Diseases*. Daya Publ. House, New Delhi.
- Sharma RC and Sharma JN. (Eds). 1995. *Integrated Plant Disease Management*. Scientific Publ., Jodhpur.

I. **Course Title : Diseases of Field and Medicinal Crops**

II. **Course Code : PL PAT 515**

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

IV. **Theory**

Unit I

Diseases of Cereal crops- Rice, wheat, barley, pearl millet, sorghum and maize.

Unit II

Diseases of Pulse crops- Gram, urdbean, mungbean, lentil, pigeonpea, soybean and cowpea.

Unit III

Diseases of Oilseed crops- Rapeseed and mustard, sesame, linseed, sunflower, groundnut, castor.

Unit IV

Diseases of Cash crops- Cotton, sugarcane.

Unit V

Diseases of Fodder legume crops- Berseem, oats, guar, lucerne.

Unit VI

Medicinal crops- *Plantago*, liquorice, mulathi, rosagrass, sacred basil, mentha, ashwagandha, *Aloe vera*.

v. Practical

- Detailed study of symptoms and host parasite relationship of important diseasesof above mentioned crops;
- Collection and dry preservation of diseased specimens of important crops.

vi. Suggested Reading

- Joshi LM, Singh DV and Srivastava KD. 1984. *Problems and Progress of Wheat Pathology in South Asia*. Malhotra Publ. House, New Delhi.
- Rangaswami G. 1999. *Diseases of Crop Plants in India*. 4th Ed. Prentice Hall of India, New Delhi.
- Ricanel C, Egan BT, Gillaspie Jr AG and Hughes CG. 1989. *Diseases of Sugarcane, Major Diseases*. Academic Press, New York.
- Singh RS. 2017. *Plant Diseases*. 10th Ed. Medtech, New Delhi.
- Singh US, Mukhopadhyay AN, Kumar J and Chaube HS. 1992. *Plant Diseases of Internatiobnal Importance*. Vol. I. *Diseases of Cereals and Pulses*. Prentice Hall, Englewood Cliffs, New Jersey.

I. **Course Title : Diseases of Fruits, Plantation and Ornamental Crops**

II. **Course Code : PL PATH 516**

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

IV. **Aim of the course**

To acquaint with diseases of fruits, plantation, ornamental plants and their management.

V. **Theory**

Unit I

Introduction, symptoms and etiology of different fruit diseases. Factors affecting disease development in fruits like apple, pear, peach, plum, apricot, cherry, walnut, almond, strawberry, citrus, mango, grapes, guava, ber, banana, pineapple, papaya, fig, pomegranate, date palm, custard apple and their management.

Unit II

Symptoms, mode of perpetuation of diseases of plantation crops such as tea, coffee, rubber and coconut and their management.

Unit III

Symptoms and life cycle of pathogens. Factors affecting disease development of ornamental plants such as roses, gladiolus, tulip, carnation, gerbera orchids, marigold, chrysanthemum and their management.

VI. **Practical**

- Detailed study of symptoms and host parasite relationship of representative diseases of plantation crops;
- Collection and dry preservation of diseased specimens of important crops.

VII. **Suggested Reading**

- Gupta VK and Sharma SK. 2000. *Diseases of Fruit Crops*. Kalyani Publishers, New Delhi.
- Pathak VN. 1980. *Diseases of Fruit Crops*. Oxford & IBH, New Delhi.
- Singh RS. 2000. *Diseases of Fruit Crops*. Oxford & IBH, New Delhi. Walker JC. 2004. *Diseases of Vegetable Crops*. TTPP, India.

I. **Course Title : Diseases of Vegetable and Spices Crops**
II. **Course Code : PL PATH 517**
III. **Credit Hours : 2+1**

IV. **Aim of the course**

To impart knowledge about symptoms, epidemiology of different diseases of vegetables and spices and their management.

V. **Theory**

Unit I

Nature, prevalence, factors affecting disease development of tuber, bulb, leafy vegetable, crucifers, cucurbits and solanaceaous vegetables. Diseasesof crops underprotected cultivation.

Unit II

Symptoms and management of diseases of different root, tuber, bulb, leafy vegetables, crucifers, cucurbits and solanaceaous vegetable crops.

Unit III

Symptoms, epidemiology and management of diseases of different spice crops such as black pepper, nutmeg, saffron, cumin, coriander, turmeric, fennel, fenugreek and ginger. Biotechnological approaches in developing disease resistant transgenics.

VI. Practical

- Detailed study of symptoms and host pathogen interaction of important diseasesof vegetable and spice crops.

VII. Suggested Reading

- Chaube HS, Singh US, Mukhopadhyay AN and Kumar J. 1992. *Plant Diseases of International Importance*. Vol. II. *Diseases of Vegetable and Oilseed Crops*. Prentice Hall, EnglewoodCliffs, New Jersey.
- Gupta VK and Paul YS. 2001. *Diseases of Vegetable Crops*. Kalyani Publishers, New Delhi Gupta SK and Thind TS. 2006. *Disease Problem in Vegetable Production*. Scientific Publ., Jodhpur. Sherf AF and Mcnab AA. 1986. *Vegetable Diseases and their Control*. Wiley Inter Science, Columbia.
- Singh RS. 1999. *Diseases of Vegetable Crops*. Oxford & IBH, New Delhi. Walker JC. 1952. *Diseases of Vegetable Crops*. McGraw-Hill, New York.

I. Course Title : Post-Harvest Diseases

II. Course Code : PL PATH 518

III. Credit Hours : 1+1

IV. Aim of the course

To acquaint with the post-harvest diseases of agricultural produce and their eco-friendly management.

V. Theory

Unit I

Concept of post-harvest diseases, definitions, importance with reference to management and health, principles of plant disease management as pre-harvest and post-harvest, Types of post-harvest problems both by biotic and abiotic factors.

Unit II

Role of physical environment, agro-ecosystem leading to quiescent infection, operational mechanisms and cultural practices in perpetuation of pathogens,

pathogens and antagonist and their relationship, role of biocontrol agents and chemicals in controlling post-harvest diseases, comparative approaches to controlof plant pathogens by resident and introduced antagonists.

Unit III

Integrated approaches in controlling diseases and improving the shelf life of produce using nutritional, bio-control agents and other agents, control of aflatoxigenic and mycotoxigenic fungi, application and monitoring for health hazards.

Unit IV

Study of symptoms, toxicosis of various pathogens, knowledge of Codex Alimentarious for each product and commodity. Physical and biological agents/ practices responsible for development/ prevention of post-harvest diseases- traditional and improved practices.

VI. **Practical**

- Isolation, characterization and maintenance of post-harvest pathogens, applicationof antagonists against pathogens *in vivo* condition;
- Comparative efficacy of different fungicides and bioagents;
- Study of different post-harvest disease symptoms on cereals, pulses, oilseed, commercial crops, vegetables, fruits and flowers;
- Visit to cold storage.

VII. **Suggested Reading**

- Chaddha KL and Pareek OP. 1992. *Advances in Horticulture* Vol. IV, Malhotra Publ. House, New Delhi.
- Pathak VN. 1970. *Diseases of Fruit Crops and their Control*. IBH Publ., New Delhi.

I. **Course Title : Plant Quarantine and Regulations**

II. **Course Code : PL PATH 519**

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

IV. **Aim of the course**

To acquaint the learners about the principles and the role of plant quarantine in containment of pests and diseases, plant quarantine regulations and set-up.

V. **Theory**

Unit I

Historical development in plant quarantine, Definitions of pest, andtransgenics as per Govt. notification; Organizational set up of plant quarantine in India. relative importance; quarantine – domestic and international. Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case histories of exotic pests/ diseases and their status.

Unit II

Acts related to registration of pesticides and transgenics. History of quarantine legislations, Salient features of PQ Order 2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

Unit III

Identification of pest/ disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniques to detect pest/ pathogen infestations; VHT and other safer techniques of disinfestation/ salvaging of infected material.

Unit IV

WTO regulations; non-tariff barriers; Pest risk analysis, good laboratory practices for pesticide laboratories; pesticide industry; Sanitary and Phytosanitary measures. Visit to plant quarantine station and PEQ facilities.

VI. Suggested Reading

- Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.
- Rhower GG. 1991. Regulatory Plant Pest Management. In: *Handbook of Pest Management in Agriculture*. 2nd Ed. Vol. II. (Ed. David Pimental). CRC Press.

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

Course Code	Course Title	Credits Hours
PL PATH 601	Advances in Mycology	2+1
PL PATH 602	Advances in Plant Virology	2+1
PL PATH 603	Advances in Plant Pathogenic Prokaryotes	2+1
PL PATH 604**	Molecular Basis of Host-pathogen Interaction	2+1
PL PATH 605	Principles and Procedures of Certification	1+0
PL PATH 606	Plant Biosecurity and Biosafety	2+0
PL PATH 691	Doctoral Seminar – I	0+ 1
PL PATH 692	Doctoral Seminar – II	0+ 1
PL PATH 699	Doctoral Research	0+75

**Core Courses for Doctoral Programme

I. Course Title : Advances in Mycology

II. Course Code : PL PATH 601

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint with the advances in mycology

V. Theory

Unit I

General introduction, historical development and advances in mycology. Recent taxonomic criteria, morphological criteria for classification. Serological, chemical (chemotaxonomy), molecular and numerical (computer based assessment) taxonomy. Interaction between groups: Phylogeny, Micro conidiation, conidiogenesis and sporulating structures of fungi imperfecti.

Unit II

Population biology, pathogenic variability/ vegetative compatibility. Heterokaryosis and parasexual cycle. Sex hormones in fungi. Pleomorphism and speciation in fungi. Mechanism of nuclear inheritance. Mechanism of extra-nuclear inheritance. Biodegradation.

Unit III

Ultra structures and chemical constituents of fungal cells, functions of cell organelles. Mitosis, meiosis, gene action and regulation. Effects of fungal interaction with host plants and other microorganisms; parasitism, symbiosis and commensalism.

Unit IV

Genetic Improvement of Fungal strains. Fungal biotechnology. Fungi mediated synthesis of nano particles – characterization process and application. Mycotoxins problems and its management.

VI. Practical

- Isolation, purification and identification of cultures, spores and mating typedetermination;
- Study of conidiogenesis-Phialides, porospores, arthospores;
- Study of fruiting bodies in Ascomycotina;
- Identification of fungi up to species level;
- Study of hyphal anastomosis;
- Morphology of representative plant pathogenic genera form different groups of fungi;

- Molecular characterization of fungi.

VII. Suggested Reading

- Alexopoulos CJ, Mims CW and Blackwell M. 1996. *Introductory Mycology*. John Wiley & Sons, New York.
- Dube HC. 2005. *An Introduction to Fungi.* 3rd Ed. Vikas Publ. House, New Delhi.
- Kirk PM, Cannon PF, David JC and Stalpers JA. (Eds.). 2001. *Ainsworth and Bisby's Dictionary of Fungi*. 9th Ed., CABI, Wallington.
- Maheshwari R. 2016. *Fungi: Experimental Methods in Biology* 2nd edn. CRC Press, US.
- Ulloa M and Hanlin RT. 2000. *Illustrated Dictionary of Mycology*. APS, St. Paul, Minnesota. Webster J and Weber R. 2007. *Introduction to Fungi.* Cambridge University Press, Cambridge.

I. Course Title : Advances in Plant Virology

II. Course Code : PL PATH 602

III. Credit Hours : 2+1

IV. Aim of the course

To educate about the advanced techniques and new developments in plant virology.

V. Theory

Unit I

Origin, evolution and interrelationship with animal viruses. Virus morphology, structure, architecture, replication (overview of host and viral components required), assembly and virus specific cytological effects in infected plant cells. Mechanisms leading to the evolution of new viruses/ strains: mutation, recombination, pseudo- recombination, component re-assortment, etc.

Unit II

Major vector groups of plant viruses and their taxonomy, virus-vectorrelationship, molecular mechanism of virus transmission by vectors. Terminologies used in immunology and serology. Classification, structure and functions of various domains of Immunoglobulins. Production of Polyclonal and monoclonal antibodies for detection of viruses. Immuno/ serological assays (Slide agglutination tests, Test tube precipitation test, Double agar diffusion test, ELISA (DAC, DAS, TAS), Dot Immuno Binding Assay, and nucleic acid based assays for detection of plant viruses.

Unit III

Polymerase Chain Reaction based (PCR, reverse transcriptase PCR, multiplex PCR, Nested PCR, Real time/ q PCR) and non PCR based: LAMP,Fluorescent *in situ* hybridization (FISH), dot blot hybridization. Plant virus genome organization (General properties of plant viral genome- information content, coding and non- coding regions), replication, transcription and translational strategies of pararetroviruses, geminiviruses, tobamo-, poty-, bromo, cucumo, ilar, tospoviruses,satellite viruses and satellite RNA.

Unit IV

Gene expression, regulation and viral promoters.Genetic engineering with plant viruses, viral suppressors, RNAi dynamics and resistant genes. Virus potential as vectors, genetically engineered resistance, transgenic plants. Techniques and application of tissue culture for production of virus free planting materials. Phylogenetic grouping system based on partial/ complete sequences of virus genomes and using of next generation sequencing technology in plant virus discovery.

VI. Practical

- Purification of viruses, SDS-PAGE for molecular weight determination, production of polyclonal antiserum, purification of IgG and conjugate preparation;
- Acquaintance with different serological techniques (i) DAC- ELISA (ii) DAS-ELISA (iii) DIBA (iv) Western blots (v) (ab) 2-ELISA. Nucleic acid isolation, DOT-blot, southern hybridization, probe preparation,and autoradiography;
- PCR application and viral genome cloning of PCR products, plasmid purification, enzyme digestion, sequencing, annotation of genes, analysis of viral sequences (use of gene bank, blast of viral sequences and phylogeny);
- Bioinformatics analysis tools for virology (ORF finder, Gene mark, Gene ontology,BLAST, Clustal X/W, Tm pred and Phylogeny programs).

VII. Suggested Reading

- Davies 1997. *Molecular Plant Virology: Replication and Gene Expression*. CRC Press, Florida. Fauquet *et al*. 2005. *Virus Taxonomy*. VIII Report of ICTV. Academic Press, New York.
- Gibbs A and Harrison B. 1976. *Plant Virology – The Principles*. Edward Arnold, London. Jones P, Jones PG and Sutton JM. 1997. *Plant Molecular Biology: Essential Techniques*. John Wiley & Sons, New York.

- Khan J A and Dijkstra. 2002. *Plant Viruses as Molecular Pathogens*. Howarth Press, New York.
- Maramorosch K, Murphy FA and Shatkin AJ. 1996. *Advances in Virus Research*. Vol. 46. Academic Press, New York.
- Pirone TP and Shaw JG. 1990. *Viral Genes and Plant Pathogenesis*. Springer Verlag, New York.
- Roger Hull. 2002. *Mathew's Plant Virology* (4th Ed.). Academic Press, New York. Thresh JM. 2006. *Advances in Virus Research.* Academic Press, New York.

I. **Course Title : Advances in Plant Pathogenic Prokaryotes**

II. **Course Code : PL PATH 603**

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

IV. **Aim of the course**

To learn about the latest developments in all the plant pathogenic prokaryotes asa whole.

V. **Theory**

Unit I

Prokaryotic cell: Molecular basis for **o**rigin and evolution of prokaryotic life, RNA world, prokaryotic cytoskeletal proteins. Flagella structure, assembly and regulation. Structure and composition (bacteria) cell wall/ envelop, Types of secretion systems (TI to TIV) and their molecular interaction, fimbriae and pili (Type IV pili), Bacterial chromosomes and plasmids, other cell organelles. Growth, nutrition and metabolism in prokaryotes (Embden-Meyerhof-Parmas (EMP) pathway, Phosphoketolase Pathway and Entner Doudoroff Pathway).

Unit II

Current trends in taxonomy and identification of phytopathogenic prokarya**:**

International code of nomenclature, Polyphasic approach, New/ special detection methods for identification of bacterial plant pathogens. Taxonomic ranks hierarchy; Identification, Advances in classification and nomenclature.

Unit III

Bacterial genetics**:** General mechanism of variability (mutation), specialized mechanisms of variability. Transposable genetic elements in bacteria- integron and prophages, Mechanism of gene transfer. Pathogenicity islands, horizontal gene transfer, Bacterial Pan-Genome.

Unit IV

Bacteriophages: Composition, structure and infection. Classification and use of phages in plant pathology/ bacteriology. Host pathogen interactions: Molecular mechanism of pathogenesis: Pathogenicity factors of soft rot, necrosis, wilt, canker, etc. Immunization, induced resistance/ Systemic Acquired Resistance, Quorum sensing. Bacterial pathogenicity and virulence**:** Molecular mechanism of virulence and pathogenesis, bacterial secretion systems, pathogenicity of bacterial enzymes that degrade the cell walls, Role of hrp/ hrc genes and TALE effectors. Synthesisand regulationof EPSs.

Unit V

Beneficial Prokaryotes-Endophytes, PGPR, Phylloplane bacteria and their role in disease management. Endosymbionts for host defence. Advances in management of diseases caused by prokaryotes: genetic engineering, RNA silencing; CRISPR cas9.

VI. Practical

- Pathogenic studies and race identification, plasmid profiling of bacteria, fatty acid profiling of bacteria, RFLP profiling of bacteria and variability status, Endospore, Flagella staining, Test for secondary metabolite production, cyanides, EPS, siderophore, specific detection of phytopathogenic bacteria using species/ pathovar specific primers;
- Basic techniques in diagnostic kit development, Molecular tools to identify phytoendosymbionts;
- Important and emerging diseases and their management strategies.

VII. Suggested Reading

- Dale JW and Simon P. 2004. *Molecular Genetics of Bacteria.* John Wiley & Sons, New York. Garrity GM, Krieg NR and Brenner DJ. 2006. *Bergey's Manual of Systematic Bacteriology: The Proteobacteria.* Vol. II. Springer Verlag, New York.
- Gnanamanickam SS. 2006. *Plant-Associated Bacteria*. Springer Verlag, New York.
- Mount MS and Lacy GH. 1982. *Plant Pathogenic Prokaryotes*. Vols. I, II. Academic Press, New York.
- Sigee DC. 1993. *Bacterial Plant Pathology: Cell and Molecular Aspects*. Cambridge Univ. Press, Cambridge.
- Starr MP. 1992. *The Prokaryotes*. Vols. I–IV. Springer Verlag, New York.

I. **Course Title : Molecular Basis of Host-pathogen Interaction**

II. **Course Code : PL PATH 604**

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

IV. **Aim of the course**

To understand the concepts of molecular biology and biotechnology in relation tohost plant- pathogen interactions.

V. **Theory**

Unit I

History of host plant resistance and importance to Agriculture. Importance and role of biotechnological tools in plant pathology. Basic concepts and principles to study host pathogen relationship. Molecular genetics, imaging and analytical chemistry tools for studying plants, microbes, and their interactions.

Unit II

Different forms of plant-microbe interactions and nature of signals/ effectors underpinning these interactions. Plant innate immunity: PAMP/ DAMP. Molecular basis of host-pathogen interaction-fungi, bacteria, viruses and nematodes; recognition system, signal transduction.

Unit III

Induction of defence responses- HR, Programmed cell death, reactive oxygen species, systemic acquired resistance, induced systemic resistance, pathogenesis related proteins, phytoalexins and virus induced gene silencing. Molecular basis of gene- for-gene hypothesis; R-gene expression and transcription profiling, mapping and cloning of resistance genes and marker-aided selection, pyramiding of R genes. Gene for gene systems: Background, genetics, phenotypes, molecular mechanisms, races, breakdown of resistance (boom-and- bust cycles), Coevolution-arms race and trench warfare models, Metapopulations, cost of resistance, cost of unnecessary virulence, GFG in agricultural crops vs. natural populations, Durability of resistance, erosion of quantitative resistance.

Unit IV

Pathogen population genetics and durability, viruses vs cellular pathogens.Gene deployment, cultivar mixtures. Disease emergence, host specialization. Circadian clock genes in relation to innate immunity. Biotechnology and disease management; development of disease resistance plants using genetic engineering approaches, different methods of gene transfer, biosafety issues related to GM crops.

VI. **Practical**

- Protein, DNA and RNA isolation, plasmid extraction, PCR analysis, DNA and Protein electrophoresis, bacterial transformation;
- Gene mapping and marker assisted selection;
- Development and use of molecular markers in identification and characterizationof resistance to plant pathogens and their management.

VII. **Suggested Reading**

- Chet I. 1993. *Biotechnology in Plant Disease Control.* John Wiley & Sons, New York.
- Gurr SJ, McPohersen MJ and Bowlos DJ. (Eds.). 1992. *Molecular Plant Pathology – A Practical Approach.* Vols. I & II, Oxford Univ. Press, Oxford.
- Mathew JD. 2003. *Molecular Plant Pathology*. Bios Scientific Publ., UK.
- Ronald PC. 2007. *Plant-Pathogen Interactions: Methods in Molecular Biology*. Humana Press, New Jersey.
- Stacey G and Keen TN. (Eds.). 1996. *Plant Microbe Interactions*. Vols. I-III. Chapman & Hall, New York; Vol. IV. APS Press, St. Paul, Minnesota.

I. **Course Title : Principles and Procedures of Certification**

II. **Course Code : PL PATH 605**

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

IV. **Aim of the course**

To acquaint with the certification procedures of seed and planting material.

V. **Theory**

Unit I

Introduction to certification. International scenario of certification and role of ISTA, EPPO, OECD, etc. in certification and quality control. Case studies of certification systems of USA and Europe. National Regulatory mechanism and certification system including seed certification, minimum seed certification standards. National status of seed health in seed certification. Methods for testing genetic identity, physical purity, germination percentage, seed health, etc. Fixing tolerance limitsfor diseases and insect pests in certification and quality control programmes.

Unit II

Methods used in certification of seeds, vegetative propagules and *in-vitro* cultures. Accreditation of seed testing laboratories. Role of seed/ planting material health certification in national and international trade.

VI. **Reference**

- Association of Official Seed Certifying Agencies. Hutchins D and Reeves JE. (Eds.). 1997. Seed Health Testing: Progress Towards the 21st Century. CABI, UK. ISHI-veg Manual of Seed Health Testing Methods.
- ISHI-F Manual of Seed Health Testing Methods. ISTA Seed Health Testing Methods.
- Tunwar NS and Singh SV. 1988. Indian Minimum Seed Certification Standards. Central Seed Certification Board, Department ofAgriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi. US National Seed Health System.

e-resources

http://www.aosca.org/index.htm.
http://www.worldseed.org/enus/international_seed/ishi_vegetable.html
http://www.worldseed.org/en-us/international _seed/ ishi_f.html
http://www.seedtest.org/en/content—1—1132—241.html
http://www.seedhealth.org

I. **Course Title : Plant Biosecurity and Biosafety**

II. **Course Code : P L PATH 606**

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

IV. **Aim of the course**

To facilitate deeper understanding on plant biosecurity and biosafety issues inagriculture.

V. **Theory**

Unit I

History of biosecurity, Concept of biosecurity, Components of biosecurity, Quarantine, Invasive Alien Species, Biowarfare, Emerging/ resurgence of pests and diseases. Introduction and History of biosecurity and its importance.

Unit II

National Regulatory Mechanism and International Agreements/ Conventions, viz., Agreement on Application of Sanitary and Phytosanitary (SPS) Measures. World Trade Organization (WTO), Convention on Biological Diversity (CBD), International Standards for Phytosanitary Measures, pest risk analysis, risk assessment models, pest information system, early warning and forecasting system, use of Global Positioning System (GPS) and Geographic

Information System (GIS) for plant biosecurity, pest/ disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity.

Unit III

Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, Issues related to release of genetically modified crops. Emerging/ resurgence of pests and diseases in the changing scenario of climatic conditions. Issues related to release of genetically modified crops.

VI. Suggested Reading

- Biosecurity: A Comprehensive Action Plan.Biosecurity Australia.
- Biosecurity for Agriculture and Food Production. FAO Biosecurity Toolkit 2008.
- Grotto Andrew J and Jonathan B Tucker. 2006. Biosecurity Guidance.
- Khetarpal RK and Kavita Gupta 2006. Plant Biosecurity in India – Status and Strategy. Asian Biotechnology and Development Review **9**(2): 3963.
- Randhawa GJ, Khetarpal RK, Tyagi RK and Dhillon BS (Eds.). 2001. Transgenic Crops andBiosafety Concerns. NBPGR, New Delhi.

e-resources

http://www.inspection.gc.ca/english/anima/heasan/fad/biosecure.*sht ml* www.fao.org/docrep/010/a1140e/a1140e00.htm Laboratory http://www.who.int/ csr/resources/publications/biosafety/WHO_CD S_EPR_2006.pdf http://www. americanprogress.org/kf/biosecurity_ a_comprehensive_ action_plan.pdf www.biosecurity.govt.nz DEFRA. www.defra.gov.uk/animalh/ diseases/control/biosecurity/ index.htm

www.daff.gov.au/ba;www.affa.gov.au/biosecurityaustralia Biosecurity New Zealand. http://www.fao.org/biosecurity/ CFIA.

VII. List of Journals

- *Annals of Applied Biology* – Cambridge University Press, London
- *Annals of Plant Protection Sciences*- Society of Plant Protection, IARI, New Delhi
- *Annual Review of Phytopathology* – Annual Reviews, Palo Alto,California
- *Annual Review of Plant Pathology* – Scientific Publishers, Jodhpur
- *Canadian Journal of Plant Pathology* – Canadian Phytopathological Society, Ottawa
- *Indian Journal of Biotechnology* – National Institute of Science Communicationand Information Resources, CSIR, New Delhi

- *Indian Journal of Mycopathological Research* – Indian Society of Mycology, Kolkata.
- *Indian Journal of Plant Protection* – Plant Protection Association of India, NBPGR,Hyderabad.
- *Indian Journal of Virology* – Indian Virological Society, New Delhi
- *Indian Phytopathology*-Indian Phytopathological Society, IARI New Delhi.
- Journal of Mycology and Plant Pathology – Society of Mycology and Plant Pathology,Udaipur.
- *Journal of Plant Disease Science*- Association of Plant Pathologists (Central India)PDKV, Akola.
- *Journal of Phytopathology* – Blackwell Verlag, Berlin
- *Mycologia* – New York Botanical Garden, Pennsylvania
- *Mycological Research* – Cambridge University Press, London
- *Physiological Molecular Plant Pathology* – Academic Press, London – *Phytopathology* – American Phytopathological Society, USA
- *Plant Disease* – The American Phytopathological Society, USA
- *Plant Disease Research* – Indian Society of Plant Pathologists, Ludhiana
- *Plant Pathology* – British Society for Plant Pathology, Blackwell Publ.
- *Review of Plant Pathology* – CAB International, Wallingford
- *Virology*- New York Academic Press e-Resources
- www.shopapspress.org
- www.apsjournals.apsnet.org
- www.apsnet.org/journals
- www.cabi_publishing.org
- www.springer.com/life+Sci/agriculture
- www.backwellpublishing.com
- www.csiro.au
- www.annual-reviews.org

NEMATOLOGY

Course Title with Credit Load for M.Sc. in Nematology

Course Code	Course Title	Credit Hours
NEMA 501*	Principles of Nematology	2+1
NEMA 502	Principles of Taxonomy	2+0
NEMA 503*	Structural and Functional Organization of Nematodes	2+1
NEMA 504*	Nematode Systematics	2+1
NEMA 505*	Nematological Techniques	1+2
NEMA 506*	Nematode Diseases of Crops	2+1
NEMA 507	Nematode Biology and Physiology	2+1
NEMA 508	Nematode Ecology	2+1
NEMA 509	Nematode Interactions with Other Organisms	2+1
NEMA 510*	Nematode Management	2+1
NEMA 511	Beneficial Nematodes	1+1
NEMA 512	Principles of Integrated Pest Management	1+1
NEMA 513	Disease Resistance in Plants	2+0
NEMA 514	Plant Quarantine, Biosafety and Biosecurity	2+0
NEMA 515	IPM in Protected Cultivation	2+1
NEMA 591	Master's Seminar	0+1
NEMA 599	Master's Research	0+30

*Core Courses for Master's

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

II. **Course Code** : **NEMA 501**

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

IV. **Aim of the course**

To project the importance of nematodes in agriculture and impart basic knowledgeon all aspects of plant nematology.

V. **Theory**

Unit I

Characteristics of Phylum Nematoda and its relationship with other related phyla, history and growth of Nematology; nematode habitats and diversity-plant, animal and human parasites; useful nematodes; economic importance of nematodes to agriculture, horticulture and forestry.

Unit II

Gross morphology of plant parasitic nematodes; broad classification, nematodebiology, physiology and ecology.

Unit III

Types of parasitism; nature of damage and general symptomatology; interaction ofplant-parasitic nematodes with other organisms.

Unit IV

Plant nematode relationships, cellular responses to infection by important phytonematodes; physiological specialization among phytonematodes.

Unit V

Principles and practices of nematode management; integrated nematode management.

Unit VI

Emerging nematode problems, Importance of nematodes in international trade andquarantine.

VI. **Practical**

- Studies on kinds of nematodes- free-living, animal, insect and plant parasites;
- Nematode extraction from soil;
- Extraction of migratory endoparasites, staining for sedentary endoparasites;
- Examination of different life stages of important plant parasitic nematodes, theirsymptoms and histopathology.

VII. **Suggested Reading**

- Dropkin VH. 1980. *An Introduction to Plant Nematology*. John Wiley & Sons, New York. Maggenti AR. 1981. *General Nematology*. Springer-Verlag, New York.
- Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed. CABI Publishing: Wallingford, UK.
- Perry RN, Moens M and Starr J.L. 2009. *Root-knot nematodes*, CABI Publishing: Wallingford, UK.
- Thorne G. 1961. *Principles of Nematology*. McGraw Hill, New Delhi.
- Walia RK and Bajaj HK. 2003. *Text Book on Introductory Plant Nematology*. ICAR, New Delhi.
- Walia RK. and Khan MR. 2018. *A Compendium of Nematode Diseases of Crop Plants,* ICAR-AICRP (Nematodes), IARI, New Delhi.

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

II. **Course Code** : **NEMA 502**

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

IV. **Aim of the course**

To sensitize the students on the theory and practice of classifying organisms andthe rules governing the same.

V. **Theory**

Unit I

Introduction to history and principles of systematics and importance. Levels and functions of systematics. Identification, purpose, methods- character matrix, taxonomic keys. Descriptions- subjects of descriptions, characters, nature of characters, analogy vs homology, parallel vs convergent evolution, intra-specific variation in characters, polythetic and polymorphic taxa, sexual dimorphism.

Unit II

Classification of animals: Schools of classification- Phenetics, Cladistics and Evolutionary classification. Components of Biological Classification: Hierarchy, Rank, Category and Taxon. Species concepts, cryptic, sibling and etho-species, infra-specific categories. Introduction to numerical, biological and cytogenetical taxonomy.

Unit III

Nomenclature: Common vs Scientific names. International Code of Zoological Nomenclature, criteria for availability of names, validity of names. Categories of names under consideration of ICZN. Publications, Principles of priority, and homonymy, synonymy, type concept in zoological nomenclature. Speciation, anagenesis vs cladogenesis, allopatric, sympatric and parapatric processes.

VI. Suggested Reading

- Blackwelder RE. 1967. *Taxonomy – A Text and Reference Book.* John Wiley & Sons, New York. Kapoor VC. 1983. *Theory and Practice in Animal Taxonomy*. Oxford & IBH, New Delhi.
- Mayr E. 1971. *Principles of Systematic Zoology*. Tata McGraw-Hill, New Delhi.
- Quicke DLJ. 1993. Principles and Techniques of Contemporary Taxonomy. Black i.e, London.

I. Course Title : Structural and Functional Organization of Nematodes

II. Course Code : NEMA 503

III. Credit Hours : 2+1

IV. Aim of the course

Familiarization with structural organization of nematode body so as to enable the students to understand biology, physiology and classification of nematodes.

V. Theory

Unit I

Introduction and general organization of nematode body; Morphology and anatomyof nematode cuticle, hypodermis, musculature and pseudocoelom.

Unit II

Digestive system- Structural variations of stoma, oesophagus, intestine and rectumin nematodes.

Unit III

Reproductive system- Variations in female and male reproductive systems, typesof reproduction, spermatogenesis and oogenesis.

Unit IV

Types and structure of excretory-secretory systems; nervous system and associatedsense organs.

Unit V

Embryogenesis, Cell lineage and postembryonic development; Process of hatchingand moulting.

VI. Practical

- Studies on variations in nematode shapes and sizes, morphological details of cuticle, cuticular markings and ornamentation, variations in stoma, oesophagus, rectum;

- Types and parts of female and male reproductive systems, sense organs, andexcretory system.

VII. Suggested Reading

- Bird AF and Bird J. 1991. *The Structure of Nematodes*. Academic Press, New York.
- Chitwood BG and Chitwood MB. 1950. *An Introduction to Nematology*. Univ. Park Press, Baltimore.
- Maggenti AR. 1981. *General Nematology*. Springer-Verlag, New York.
- Malakhov VV. 1994. *Nematodes: Structure, Development, Classification and Phylogeny*.
- Smithsonian Institution Press, Washington DC.

I. Course Title : Nematode Systematics

II. Course Code : NEMA 504

III. Credit Hours : 2+1

IV. Aim of the course

Understanding concepts in nematode taxonomy, development of skills in the identification of plant parasitic nematodes up to genera and species levels.

V. Theory

Unit I

Gross morphology, principles of nematode taxonomy -levels of taxonomy, systematics vs. taxonomy, morpho-taxonomy, molecular taxonomy, identification, classification, taxonomic categories, taxonomic characters, morphometry, Zoological nomenclature, species concept and speciation (allopatric and sympatric).

Unit II

Taxonomic position of nematodes and their relationships with allied groups;

Classification and diagnoses of nematodes up to ordinal rank (Secernentea and Adenophorea)

Unit III

Taxonomy of free living nematodes

Unit IV

Classification of plant parasitic nematodes; Order Tylenchida and diagnoses of its sub-orders, super families, families and important genera; Order Aphelenchida, Dorylaimida and Triplonchida and diagnoses of their important genera.

VI. Practicals

- Collection of soil and plant samples from different habitats,processing and preservation of samples; and preparation of temporary mounts, processing of nematode specimens and permanent mounts;

- Preparation of en face view and TS of nematodes, perineal pattern of root knotnematodes and cone-top structure for cyst nematodes;
- Identification of soil and plant nematodes from nematode suspension and mounted slides;
- Camera lucida drawing of nematodes, measurement of nematodes using traditional as well as image analyzing software;
- Procedures for PCR- Taxonomy.

VII. Suggested Reading

- Ahmad W and Jairajpuri MS. 2010. *Mononchida: The Predatory Soil Nematodes, Series: Nematology Monographs and Perspectives*, Volume: 7, Brill.
- Geraert E. 2006. *Tylenchida*. Brill.
- Hunt DJ. 1993. *Aphelenchida, Longidoridae and Trichodoridae – their Systematics and Bionomics*. CABI, Wallingford.
- Jairajpuri MS and Ahmad W. 1992. *Dorylaimida: Free-Living, Predaceous and Plant-Parasitic Nematodes*, Brill.
- Mai WF, Mullin PG, Lyon HH and Loeffler K. 1996. Plant- Parasitic Nematodes: A Pictorial Key to Genera, 5th ed., Cornell University Press, London.
- Siddiqi MR. 2000. *Tylenchida: Parasites of Plants and Insects*. 2nd Ed. CABI, Wallingford.

I. Course Title : Nematological techniques

II. Course Code : NEMA 505

III. Credit Hours : (1+2)

IV. Aim of the course

Understanding the principles, theoretical aspects and developing skills in nematological techniques.

V. Theory

Unit I

Principles and use of light, scanning and transmission electron microscopes, andother laboratory equipments.

Unit II

Survey and surveillance methods; collection of soil and plant samples; techniques for extraction of nematodes from soil and plant material; estimation of population densities.

Unit III

Killing, fixing, clearing and mounting nematodes; measurements, preparation of perineal patterns, vulval cones of cyst nematodes, en-face views and body sectionof nematodes.

Unit IV

In-vitro and *in vivo* culturing techniques of plant parasitic, bacteriophagous, mycophagus and omnivorous nematodes.

Unit V

Staining nematodes in plant tissues; microtomy for histopathological studies; collection of plant root exudates and their bioassay; preparation of plant materials for exhibition.

Unit VI

Application of molecular techniques in Nematology.

VI. **Practical**

- Collection of soil and plant samples;
- Extraction of nematodes from soil by Baermann funnel, sieving and decanting,elutriation and sugar centrifugal methods;
- Extraction of cysts from soil;
- Extraction of nematodes from plant material;
- Estimation of population densities;
- Staining plant material for nematodes;
- Killing and fixing nematodes, clearing nematodes by slow and Seinhorst's methods;
- Preparation of temporary and permanent mounts;
- Measurements, drawing, microphotography, special preparation of nematodes – perineal patterns, vulval cones, en-face and body sections;
- Collection of root exudates, preparation of exhibits of nematode diseased plant material, *in-vitro* culturing techniques of nematodes- callous culture, excised root and carrot disc techniques.

VII. **Suggested Reading**

- Ayoub SM. 1981. Plant Nematology – An Agricultural Training Aid.
- Barker KR, Carter CC and Sasser JN. 1985. An Advanced Treatise on Meloidogyne. Vol. II.
- Methodology. International Meloidogyne Project, NCSU, Raleigh. USA.
- Manzanilla-Loìpez, RH and Marbaìn-Mendoza N. 2012. Practical Plant Nematology, Montecillo, Texcoco: Biblioteca Basica de Agricultura.
- Sikora RA, Coyne D, Hallman J and Timper P. 2018. Plant Parasitic Nematodes in Subtropical and Tropical Agriculture.3rd edn. CABI Publishing, England.

- Southey JF. 1986. Laboratory Methods for Work with Plant and Soil Nematodes. HMSO, London. Subbotin SA, Mundo-Ocampo M and Baldwin J. 2010. Systematics of The Genus Heterodera in Systematics of Cyst Nematodes (Nematoda: Heteroderinae), Part B, Series: Nematology Monographs and Perspectives, Volume: 8B, Brill.
- Zuckerman BM, Mai WF and Harrison MB. 1985. Plant Nematology Laboratory Manual. Univ. of Massachusetts.

I. Course Title : Nematode Diseases of Crops

II. Course Code : NEMA 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart basic knowledge about the causal organism, nature of damage, symptoms

V. Theory

Diagnosis of causal organism, distribution, host range, biology and lifecycle, nature of damage, symptoms, interaction with other organisms, and management of nematode diseases in different crops.

Unit I

Cereal crops- Ear-cockle and *tundu* diseases of wheat, *molya* disease of wheat and barley; rice root nematode, rice root-knot and cyst nematode problems, *ufra* and white tip diseases of rice; lesion nematodes, cyst nematodes of maize and sorghum.

Unit II

Pulses, Sugar, Fibre, Fodder and Oilseed crops- Pigeon pea cyst nematode, root knot nematode, reniform nematode, lesion, lance nematode, sugarbeet cyst and soybean cyst nematode problems.

Unit III

Vegetable crops- root-knot disease, reniform nematode, potato cystnematode; stem and bulb nematode. Nematode problems of protected cultivation.

Unit IV

Fruit crops- root-knot nematode, reniform nematode, slow decline of citrus. Flowers- root-knot nematode, foliar nematodes, bulb nematodes, Mushroom-nematode problems.

Unit V

Plantation, medicinal and aromatic crops- burrowing nematode problem of banana, spices and condiments, root-knot and lesion nematode problems ofcoffee and tea,red ring disease of coconut. Forests- Pine wilt disease.

VI. Practical

- Diagnosis of causal organisms;
- Identification of different life cycle stages;
- Study of symptoms and histopathology of nematode damage in different crops, study tours for field diagnosis of nematode problems.

VII. Suggested Reading

- Bhatti DS and Walia RK. 1992. *Nematode Pests of Crops*. CBS, New Delhi.
- Bridge J and Starr JL. 2007. *Plant Nematodes of Agricultural Importance: A Colour Handbook*, CRC Press
- Evans AAF, Trudgill DL and Webster JM. 1994. *Plant Parasitic Nematodes in TemperateAgriculture*. CABI, Wallingford.
- Nickle WR. 1991. *Manual of Agricultural Nematology*. Marcel Dekker, New York. Perry RN and Moens M. 2006. *Plant Nematology*. CABI, Wallingford.
- Perry RN, Moens M and Jones JT. 2018. *Cyst Nematodes*, CABI Publishing: Wallingford, UK. Perry RN, Moens M and Starr JL. 2009. *Root-knot nematodes*, CABI Publishing: Wallingford, UK.
- Sikora R, Coyne D, Hallmann J and Timper P. 2018. *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture*, 3rd Ed., CABI, UK.
- Walia RK and Khan MR. 2018. *A Compendium of Nematode Diseases of Crop Plants, ICAR- AICRP* (*Nematodes*), IARI, New Delhi.

I. Course Title : Nematode Biology and Physiology

II. Course Code : NEMA 507

III. Credit Hours : 2+1

IV. Aim of the course

To develop understanding of life cycle patterns, feeding and metabolic processes inhytonematodes which have implications in their management.

V. **Theory**

Unit I

Host finding and invasion, feeding, hatching, moulting; life cycle patterns in different types of nematodes.

Unit II

Types of reproduction, gametogenesis, embryogenesis and post embryogenesis.

Unit III

Chemical composition of nematodes, hydrolytic enzymes, pseudocoelom and function of transport.

Unit IV

Physiology of digestive system, intermediary metabolism.

Unit V

Osmoregulation, physiology of excretory-secretory and neuromuscular systems.

VI. **Practical**

- Studies on embryogenesis and post-embryogenesis, hatching, moulting, life cycledevelopment, feeding, enzymatic assay by electrophoresis.

VII. **Suggested Reading**

- Croll NA. 1970. *The Behaviour of Nematodes: The Activity, Senses and Responses.* Edward Arnold, London.
- Croll NA and Mathews BE. 1977. *Biology of Nematodes.* Blackie, Glasgow. Lee DL. 2002. *The Biology of Nematodes.* Taylor & Francis, London.
- Lee DL and Atkinson HJ. 1976. *Physiology of Nematodes*. MacMillan, London.
- Perry RN and Wright DJ. 1998. *The Physiology and Biochemistry of Free-living and PlantParasitic Nematodes*. CABI, Wallingford.
- Wallace HR. 1963. *The Biology of Plant Parasitic Nematodes*. Edward Arnold, London.

I. **Course Title : Nematode Ecology**

II. **Course Code : NEMA 508**

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

IV. **Aim of the course**

To understand the life of plant parasitic nematodes in their environment; their survival strategies, and how to exploit these for their control.

V. Theory

Unit I

Definition and scope; components of environment; evolution of nematodes; ecological classification, prevalence, distribution and dispersal of nematodes.

Unit II

Role of nematodes in the food web; habitat and niche characteristics; communityanalysis and population estimation models.

Unit III

Effects of abiotic and biotic factors on nematodes.

Unit IV

Environmental extremes and nematode behaviour- aggregation,swarming, orientation, feeding and reproduction.

Unit V

Survival strategies of nematodes in adverse environment and absence of host.

Unit VI

Modeling population dynamics and relations with crop performance; ecological considerations in nematode management, data interpretation and systems simulation.

VI. Practical

- Study of nematode fauna in varied agro-ecological systems;
- Community analysis of nematode populations;
- Laboratory exercises on influence of abiotic factors on movement and hatching, green-house experiments on effect of abiotic factors on nematode populations and plant growth.

VII. Suggested Reading

- Croll NA. 1970. *The Behaviour of Nematodes*: *The Activity, Senses and Responses.* Edward Arnold, London.
- Croll NA and Mathews BE. 1977. *Biology of Nematodes.* Blackie, Glasgow. Lee DL. 2002. *The Biology of Nematodes.* Taylor & Francis, London.
- Gaugler R and Bilgrami AL. 2004. *Nematode Behaviour*, CABI, UK.
- Norton DC. 1978. *Ecology of Plant Parasitic Nematodes*. John Wiley.

Poinar G. 1983. *Natural History of Nematodes.* Prentice Hall, Englewood Cliffs.

- Wallace HR. 1973. *Nematode Ecology and Plant Disease*. Edward Arnold, London.

I. **Course Title** : **Nematode Interactions with Other Organisms**

II. **Course Code** : **NEMA 509**

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

IV. **Aim of the course**

To understand the role of nematodes in disease complexes involving fungal, bacterial,viral and other organisms.

V. **Theory**

Unit I

Concept of interaction and its importance in disease complexes and their management involving nematode and other organisms

Unit II

Interaction of plant parasitic nematodes with wilt causing fungal pathogens andmicrofungi.

Unit III

Interaction of plant parasitic nematodes with root rot and other fungal pathogens.

Unit IV

Interaction of plant parasitic nematodes with bacterial pathogens, other nematodespecies and arthropods.

Unit V

Virus transmission by nematodes.

VI. **Practical**

- Green-house experiments to study the role of plant parasitic nematodes in wilt/rot causing fungal and bacterial pathogens.

VII. **Suggested Reading**

- Khan MW. 1993. *Nematode Interactions*. Chapman & Hall, New York.
- Lamberti F, Taylor CE and Seinhorst JW. 1975. *Nematode Vectors of Plant Viruses.* Plenum Press, London.
- Mondia JL and Timper P. 2016. Interactions of microfungi and plant parasitic nematodes. In:
- *Biology of Microfungi* (De-Wei-Lei Ed.). Springer Publications

- Sasser JN and Jenkins WR. 1960. *Nematology*: *Fundamentals and Recent Advances with Emphasis on Plant Parasitic and Soil Forms*. Eurasia Publ. House, New Delhi.

I. **Course Title : Nematode Management**
II. **Course Code : NEMA 510**
III. **Credit Hours : 2+1**
IV. **Aim of the course**

To impart comprehensive knowledge about the principles and practices of nematodemanagement.

V. **Theory**

Unit I

Concepts and history of nematode management; crop loss estimation, ecologicaland socio-economic aspects, cost-benefit ratios and pest risk analysis.

Unit II

Chemical methods- nematicides, their types, classification, mode of action, applicators and application methods, antidotes, and economizing nematicidal use.

Unit III

Cultural practices- crop rotations and cropping sequences, fallowing, flooding, soil solarisation, time of sowing, organic amendments of soil, bio-fumigation, antagonistic and trap crops, sanitation, etc. Physical methods- use of heat, hot water treatment and other methods of disinfestations of planting material.

Unit IV

Biological methods- concepts and terminology, use of predators and parasites as biological control agents, their mass multiplication and fielduse; phytotherapeutic methods – use of antagonistic plants and antinemic plant products.

Unit V

Genetic methods- plant resistance; legal methods- quarantine regulations; integrated management –concepts and applications

VI. **Practical**

- *In-vitro* screening of synthetic chemicals and plant products for nematicidal activity, and their application methods;
- Methods for screening of crop germplasm for resistance against nematodes, laboratory exercises on biocontrol potential of fungal, bacterial parasites, and predacious fungi and nematodes.

VII. Suggested Reading

- Bhatti DS and Walia RK. 1994. *Nematode Pest Management in Crops*. CBS, New Delhi. Brown GL. 1977. *The Nematode Destroying Fungi*. CBP, Guelph.
- Brown RH and Kerry BR. 1987. *Principles and Practice of Nematode Control in Crops*. Academic Press, Sydney.
- Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives. Vol. II: Nematode Management and Utilization.* CABI, Wallingford.
- Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed., CABI, Wallingford, London.
- Starr JL, Cook R and Bridge J. 2002. *Plant Resistance to Parasitic Nematodes.* CABI, Wallingford. Stirling GR. 2014. *Biological Control of Plant parasitic Nematodes,* 2nd Ed., CAB International, UK. Whitehead AG. 1997. *Plant Nematode Control*. CABI, Wallingford.

I. Course Title : Beneficial Nematodes

II. Course Code : NEMA 511

III. Credit Hours : 1+1

IV. Aim of the course

To sensitize about the use of nematodes for the biological control of insect pests of crops, and application of some nematodes as biological models and as indicators of environmental pollution.

V. Theory

Unit I

Beneficial nematode fauna – predators, parasites of insects, molluscs and other pests; Entomophilic nematodes- important groups, types of nematode-insect associations; taxonomic characteristics of nematode parasites of insects.

Unit II

Host-parasite relations and life cycle of mermithids, entaphelenchids, thelastomids,sphaerularids and tylenchids.

Unit III

Entomopathogenic nematodes- *Steinernema, Heterorhabditis, Oscheius* their morphological characteristics, taxonomic status, biology and mode of action.

Unit IV

Entomopathogenic nematodes- mass multiplication techniques, formulations, field applications and efficacy, success stories.

Unit V

Nematodes as biological models, nematodes as indicators of pollution, role of nematodes in organic matter recycling.

VI. Practical

Isolation, identification, mass rearing and application methods of entomopathogenicnematodes.

VII. Suggested Reading

- Gaugler R and Kaya HK. 1990. *Entomopathogenic Nematodes in Biological Control*. CRC Press, Boca Raton, Florida.
- Gaugler R. 2002. *Entomophilic Nematology*. CABI, Wallingford. Grewal PS, Ehlars RU and Shapiro DI. 2005. *Nematodes as Biocontrol Agents*. CABI, Wallingford.
- Jairajpuri MS and Khan MS. 1982. *Predatory Nematodes (Mononchida).* Associated Publ. Co., New Delhi.
- Wood WB. 1998. *The Nematode* Caenorhabditis elegans. Cold Spring Harbor Press.
- Woodring JL and Kaya HK. 1988. *Steinernematid and Heterorhabditid Nematodes: A Handbook of Techniques*. Southern Coop. Bull., Ark. Ag. Ext. Sta.
- Zuckerman BM. (Ed.). 1980. *Nematodes as Biological Models*. Vols. I, II. Academic Press, New York.

I. Course Title : Principles of Integrated Pest Management

II. Course Code : NEMA 512

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize the students with principles of insect pest management, including concept and philosophy of IPM. Train students in computation of ETL, implementingIPM programmes.

V. Theory

Unit I

History and origin, definition and evolution of various related terminologies.

Unit II

Concept and philosophy, ecological principles, economic threshold concept, and economic consideration.

Unit III

Tools of pest management and their integration- legislative, cultural, physical and mechanical methods; pest survey and surveillance, forecasting,types of surveys including remote sensing methods, factors affecting surveys; political, social and legal implications of IPM; pest risk analysis; pesticide risk analysis; cost-benefit ratios and partial budgeting; case studies of successful IPM programmes.

VI. Practical

- Characterization of agro-ecosystems;
- Sampling methods and factors affecting sampling;
- Population estimation methods;
- Crop loss assessment- direct losses, indirect losses, potential losses, avoidablelosses, unavoidable losses;
- Computation of EIL and ETL;
- Crop modeling; designing and implementing IPM system.

VII. Suggested Reading

- Dhaliwal GS and Arora R. 2003. *Integrated Pest Management – Concepts and Approaches.*
- Kalyani Publishers, New Delhi.
- Dhaliwal GS, Ram Singh and Chhillar BS. 2006. *Essentials of Agricultural Entomology*. Kalyani Publishers, New Delhi. Flint MC and Bosch RV. 1981. *Introduction to Integrated Pest Management.* 1st Ed., Springer, New York.
- Horowitz AR and Ishaaya I. 2004. *Insect Pest Management: Field and Protected Crops*. Springer, New Delhi.
- Ignacimuthu SS and Jayaraj S. 2007. *Biotechnology and Insect Pest Management*. Elite Publ.,New Delhi.
- Metcalf RL and Luckman WH. 1982. *Introduction of Insect Pest Management.* John Wiley & Sons, New York.
- Norris RF, Caswell-Chen EP and Kogan M. 2002. *Concepts in Integrated Pest Management.*
- Prentice Hall, New Delhi.

- Pedigo RL. 2002. *Entomology and Pest Management.* 4th Ed. Prentice Hall, New Delhi. Subramanyam B and Hagstrum DW. 1995. *Integrated Management of Insects in Stored Products.*
- Marcel Dekker, New York.

I. **Course Title : Disease Resistance in Plants**

II. **Course Code : NEMA 513**

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

IV. **Aim of the course**

To acquaint with disease resistance mechanisms in plants.

V. **Theory**

Unit I

Introduction and historical development, dynamics of pathogenicity, process of infection, variability in plant pathogens, gene centres as sources of resistance, disease resistance terminology.

Unit II

Disease escape, disease tolerance, disease resistance, types of resistance, identification of physiological races of pathogens, disease progression in relation to resistance, stabilizing selection pressure in plant pathogens.

Unit III

Host defence system, morphological and anatomical resistance, preformed chemicals in host defence, post infectional chemicals in host defence, phytoaleXins, hypersensitivity and its mechanisms.

Unit IV

Gene-for-gene concept, protein-for-protein and immunization basis, management ofresistance genes. Strategies for gene deployment.

I. **Suggested Reading**

- Dallice M *et al*.1996. *Molecular Aspects of Pathogenicity and Resistance: Requirement for Signal Transduction.* APS, St Paul, Minnesota.
- Deverall, B.J. 1977. *Defence Mechanisms in Plants*. Cambridge Univ. Press, Cambridge, New York.
- Parker J. 2008. *Molecular Aspects of Plant Diseases Resistance*. Blackwell Publ.
- Robinson RA. 1976. *Plant Pathosystems*. Springer Verlag, New York. Singh BD. 2005. *Plant Breeding – Principles and Methods*. 7th Ed. Kalyani Publishers, Ludhiana.

- Van der Plank JE. 1975. *Principles of Plant Infection*. Academic Press, New York.
- Van der Plank JE. 1978. *Genetic and Molecular Basis of Plant Pathogenesis*. Springer Verlag, New York.

I. **Course Title : Plant Quarantine, Biosafety and Biosecurity**

II. **Course Code : NEM 514**

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

IV. **Aim of the course**

To acquaint the learners about the principles and the role of Plant Quarantine in containment of pests and diseases, plant quarantine regulations and set-up.

V. **Theory**

Unit I

Definition of pest, pesticides and transgenics as per Govt. notification; relative importance; quarantine – domestic and international. Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case historiesof exotic pests/ diseases and their status.

Unit II

Plant protection organization in India. Acts related to registration of pesticides and transgenics. History of quarantine legislations, PQ Order2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

Unit III

Identification of pest/ disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniquesto detect pest/ pathogen infestations; VHT and other safer techniques of disinfestation/ salvaging of infected material.

Unit IV

WTO regulations; non-tariff barriers; Pest risk analysis, good laboratory practicesfor pesticide laboratories; pesticide industry; Sanitary and Phytosanitary measures.

VI. **Suggested Reading**

- Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.
- Rhower GG. 1991. Regulatory Plant Pest Management. In: *Handbook of Pest Management*
- *in Agriculture*. 2nd Ed. Vol. II. (Ed. David Pimental). CRC Press.

- Shukla A and Veda OP. 2007. *Introduction to Plant Quarantine*. Samay Prakashan, New Delhi.

I. Course Title : IPM in Protected Cultivation
II. Course Code : NEMA 515
III. Credit Hours : 2+1

IV. Aim of the course

To sensitize the pest and disease scenario developing in crops raised under protectedcultivation and to impart knowledge about the remedy.

V. Theory

Unit I

Characteristics of protected cultivation and tools for sustainable crop production outline of major biotic stresses in protected cultivation including: fungi, bacteria, virus, nematode, insects and mites.

Unit II

Sampling and monitoring pests and diseases; epidemiology and damage relationships; loss assessment; population dynamics of biotic stress agents; factors responsible for severity of pests and diseases.

Unit III

Host plant resistance to pathogens and insects; management strategies for protected cultivation: disinfestation of soil and growth media; preventive, scouting and early detection; and curative measures: biological control of sap sucking pests, leaf miners; soil- and air-borne pathogens; pesticides selectivity, applications and resistancemanagement; buzz pollination.

VI. Practical

- Visit to familiarize with pest and disease situations developing in protected cultivation;
- Symptomatology and damages; identification of the causes; estimation of population densities; management tactics/ approaches and recommendations; production and commercialization of biological agents.

VII. Learning outcome

Students are expected to be well versed with the crop pest and disease problems associated with protected cultivation and their management.

VIII. Suggested Reading

- Gullino ML, Albajes, R and Nicot P. 2019. *Integrated Pest and Disease Management in Greenhouse Crops*. Ed. 2nd, Springer, New York.
- Rathee *et al*. 2018. Integrated Pest Management under Protected Cultivation—A Review. *Journal of Entomology and Zoology Studies*, 6 (2): 1201–1208.

IX. List of Journals

- *Annals of Applied Nematology* – Society of Nematologists, USA
- *Current Nematology* – Bioved Research Society, Allahabad, India
- *Egyptian Journal of Agronematology* – Egyptian Society of Agricultural Nematology
- *Indian Journal of Nematology* – Nematological Society of India
- International Journal of Nematology – Afro-Asian Society of Nematologists, Luton
- *Japanese Journal of Nematology* – Japanese Nematological Society
- *Journal of Nematology* – Society of Nematologists, USA
- *Journal of Nematode Morphology and Systematics* –Jaen, Universidad de Jaen
- *Nematologia Brasiliera* – Brazilian Nematological Society
- *Nematologia Mediterranea* – Istituto per la Protezione delle Plante (IPP) – Sect. ofBari of the CNR, Italy
- *Nematology* – EJ Brill Academic Publishers, UK
- *Nematropica* – Organization of Nematologists of Tropical America
- *Pakistan Journal of Nematology* – Pakistan Society of Nematologists
- *Russian Journal of Nematology* – Russian Society of Nematologis

e-Resources

http://www.nematologists.org/ (The Society of Nematologists) http://nematology.ucdavis.edu/ (Deptt. of Nematology, Univ. of California, Davis) http://www.ifns.org/ (International Federation of Nematology Societies)

http://www.inaav.ba.cnr.it/nemmed.html (Nematologia Mediterranea) http://nematode.unl.edu/Nemajob.htm (Nematology Employment Bulletin Board) http://nematode.unl.edu/ (University of Nebraska – Lincoln Nematology) http://nematode.unl.edu/wormsite.htm (Links to Other Nematology Resources) http://nematode.unl.edu/SON/jon.htm (Journal of

Nematology) http://www.nematology.ucr.edu/ (Deptt. of Nematology, Univ. of California, Riverside) http://entnemdept.ifas.ufl.edu/ (Univ. of Florida, Entomology and Nematology Dept.) http://www.brill.nl/m_catalogue_sub6_id8548.htm (Nematology – journal) http://www.ars.usda.gov/main/site_main.htm?modecode=12752900 (Nematology Lab., USDA) http://flnem.ifas.ufl.edu/history/nem_history.htm (Nematology history) http://www.nematology.ugent.be/ (Nematology Unit, Ghent University)

http://www.entm.purdue.edu/nematology/ (The Purdue Nematology Lab.) http://www.bspp.org.uk/ppigb/nematolo.htm#a-z (Links to Nematology labs) http://www.nem.wur.nl/UK/ (Laboratory of Nematology, Wageningen Univ.) http://onta.ifas.ufl.edu/ (The Organization of Nematologists of Tropical America)

http://www.openj-gate.org/Articlelist.asp?Source=1&Journal_ID=103267. (Nematology Newsletter)

http://nematology.umd.edu/nematology.html (Plant Nematology Laboratory, Maryland) http://www.biology.leeds.ac.uk/nem/ (Plant Nematology Lab., University of Leeds) http://www.plantpath.iastate.edu/dept/labs/tylka/ (Iowa State University, Nematology Lab) http://nematologists.org.au/newsletters.html (Australasian Association of Nematologists) http://soilplantlab.missouri.edu/nematode/ (Plant Nematology Laboratory, Missouri) http://www.eumaine.ugent.be/ (European Master of Science in Nematology) http://www.jstage.jst.go.jp/browse/jjn (The Japanese Journal of Nematology)

Suggested Broad Topics for Master's and Doctoral Research

- Identification of key nematode pests emerging in regional agro-ecosystems
- Development of molecular diagnostic tools of phytonematodes
- Nematode problems of peri-urban and protected agriculture systems, and their management
- Role of nematodes in organic matter recycling
- Modelling nematode populations for disease forecasting and predicting yield losses
- Nematodes as indicators of environmental pollution
- Identification of cost effective nematode-suppressive cropping systems for specific agro- ecosystems
- Isolation, identification and characterization of phytochemicals for nematoxicity
- Disinfection of nematode-infected planting material through eco-friendly sanitary methods

- Characterization of molecular markers and genes governing resistance to key nematodepests
- Management of nematodes with antagonistic bacteria
- Bionomics of potential bio-control agents and their field efficacy
- Devising non-chemical methods of nematode management in mushroom cultivation
- Development of nematode management modules for IPM systems
- Field efficacy and formulation of entomopathogenic nematodes against foliar and soil-borne insect pests of crops
- Study of disease complex involving nematodes and other plant pathogens.
- Nematode suppressive rhizospheric microorganisms.
- Nematode suppressive endophytes.
- Management of nematodes using RNAi
- Factors related to entomopathogenic nematode- bacterium symbionts
- Management of root knot nematodes in protected cultivation system
- Assessment of nematode damage and yield losses in organic farming system

Course Title with Credit Load for Ph.D in Nematology

Course Code	Course Title	Credit Hours
NEMA 601**	Nematode Phylogeny and Systematics	2+1
NEMA 602**	Nematode Disease Development and Host Resistance	2+1
NEMA 603**	Advances in Nematode Management	2+1
NEMA 604**	Physiological and Molecular Nematology	2+1
NEMA 605/	Plant Biosecurity and Biosafety	2+0
NEMA 691	Doctoral Seminar I	0+1
NEMA 692	Doctoral Seminar II	0+1
NEMA 699	Doctoral Research	0+75

**Core Courses for Doctoral Programme; @Cross-listed with Plant Pathology; $Cross-listed with Entomology

I. **Course Title** : **Nematode Phylogeny and Systematics**

II. **Course Code** : **NEMA 601**

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

IV. **Aim of the course**

Concepts in Systematics, understanding nematode diversity, evaluation and analysis of taxonomic characters for inferring interrelationships among nematode groups, modern methods and tools for identification of nematodes, and phylogenetic analysis.

V. **Theory**

Unit I

Phylogenetic systematics – Evolutionary systematics, Cladistics, phylogenetic trends (morphological) and molecular phylogenetic framework for the phylum Nematoda, phylogenomics

Unit II

Taxonomic characters, numerical taxonomy, morphometry, variations,statistics in taxonomic descriptions, description of new species, preparation of illustrations,

keys and compendia for nematode species.

Unit III

Identification of common species of root knot nematodes by esterase phenotypes and race/ pathotypes of root knot/ cyst/ reniform nematodes by differential host tests.

Unit IV

Recent advances in nematode identification- molecular, biochemical, immunodiagnostic, molecular characterization and DNA finger-printing techniques.

VI. **Practical**

- Detailed studies of morphological structures and identification of plant parasiticnematodes up to species level;
- Preparation of compendia and keys;
- Drawing and measurements using camera lucida and computer software;
- Procedures for identification of species/ races of root-knot/ cyst/ reniform nematodes.

- Isozyme analysis for identification of common species of root knot nematodes. rDNA-RFLP for diagnosis of nematode species;
- Sequence analysis, alignment, phylogenetic analysis, preparation of phylogenetictree and interpretation.

VII. Suggested Reading

- Andraìssy I. 1976. *Evolution as a basis for the systematization of nematodes*. Pitman Publishing Ltd, London.
- Blackwelder RE. 1967. *Taxonomy – A Text and Reference Book.* John Wiley & Sons, New York.
- Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives. Vol. I. Nematode Morphology, Physiology and Ecology*. CABI, Wallingford.
- Fortuner R. 1988. *Nematode Identification and Expert System Technology*. NATO Science Series A: Springer US.
- Geraert E. 2006. *Nematology Monographs and Perspectives*. Vol. IV. EJ. Brill.
- Kapoor VC. 1983. *Theory and Practice in Animal Taxonomy*. Oxford & IBH, New Delhi. Mayr E. 1969. *Principles of Systematic Zoology*. Tata McGraw-Hill, New Delhi.
- Quicke DLJ. 1993. *Principles and Techniques of Contemporary Taxonomy*. Blackie, London. Stone AR, Platt HM and Khalil LF. 1983. *Concepts in Nematode Systematics*, *the Systematics*
- *Association Special Volume* No. 22, Academic Press, London and NY.

I. Course Title : Nematode Disease Development and Host Resistance

II. Course Code : NEMA 602

III. Credit Hours : 2+1

IV. Aim of the course

To update knowledge on the recent research trends in the field of plant nematoderelationships at genetic and molecular level.

V. Theory

Unit I

Mechanisms of pathogenesis, cytological and biochemical changes induced by nematode feeding.

Unit II

Plant defense systems, role of nematodes.

Unit III

phytoaleXins, etc. against major plant parasitic Genetic basis of plant resistance to nematodes and identification of resistance genes against economically important nematodes.

Unit IV

Application of biotechnological methods in the development of nematode resistant crop cultivars; resistance markers; incorporation of resistance by conventional breeding and transgenic approaches.

Unit V

Influence of microorganisms on plant nematode interactions.

VI. Practical

- Microtomy for study of histopathological changes induced by important nematodes, screening techniques for assessment of resistance in crop germplasm against nematodes.

VII. **Suggested Reading**

- Barker KR, Pederson GA and Windham GL. 1998. *Plant and Nematode Interactions*. CABI, Wallingford.
- Fenoll C, Grundler FMW and Ohl SA. 1997. *Cellular and Molecular aspects of Plant-Nematode Relationships*. Kluwer Academic Press, Dordrecht.
- Lamberti F, Giorgi C and Bird D. 1994. *Advances in MolecularPlant Nematology*. Plenum Press.

I. **Course Title : Advances in Nematode Management**

II. **Course Code : NEMA 603**

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

IV. **Aim of the course**

To keep abreast ith latest developments and trends in nematode management.

V. **Theory**

Unit I

Isolation, identification, host specificity, mode of action, culturing and field application potential of promising bio-control agents- predacious and parasitic fungi; nematoxic fungal culture filtrates.

Unit II

Isolation, identification, host specificity, mode of action, culturing and field application potential of promising bio-control agents- parasitic and nematode antagonistic bacteria; predacious mites and predacious nematodes.

Unit III

Mass culturing, formulation, quality control, bio-safety and registration protocolsof bio-control agents.

Unit IV

Phytoalexins, allelochemicals, phytotherapeutic substances, novel nematicides, deployment of resistant varieties and non-host crops in nematode suppressive cropping systems, emergence of resistance breaking biotypes, recent regulatory provisions and methods, quarantine and disinfection.

Unit V

Nematode management modules for integrated pest and disease management in cropping systems. Nematode management options and approaches for organic farming, precision farming and protected cultivation system. Application of GIS and GPS technology for surveillance and management.

VI. Practical

- Green-house experiments on the efficacy of fungal and bacterial bio-control agents, botanicals.

VII. Suggested Reading

- Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives Vol. II. Nematode Management and Utilization.* CABI, Wallingford.
- Jana BL. 2008. *Precision Farming*. Research Books and Periodicals Pvt. Ltd., Delhi. Lillesend TW, Kiefer RW and Chipman JW. 1979. *Remote Sensing and Image Interpretation*.
- John Wiley & Sons, New York.
- Perry RN and Moens M. 2013. *Plant Nematology*. 2nd Ed., CABI, Wallingford, London. Poinar GO Jr and Jansson H-B. 1988. *Diseases of Nematodes*. Vols. I, II. CRC Press, Boca Raton, Florida. Scientific Publ., Jodhpur.
- Starr JR, Cook R and Bridge J. 2002. *Plant Resistance to Parasitic Nematodes*. CABI, Wallingford.
- Stirling GR. 2014. *Biological Control of Plant parasitic Nematodes*, 2nd Ed., CAB International, UK
- Tarafdar JC, Priputhi KP and Kumar M. 2007. *Organic Agriculture*. Upadhyaya RK, Walia RK and Dubey OP. 2004. *IPM Systems in Agriculture. Vol. IX. Phytonematology*. Aditya Books, New Delhi.

I. **Course Title** : **Physiological and Molecular Nematology**

II. **Course Code** : **NEMA 604**

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

IV. **Aim of the course**

Appraisal on the application of modern biotechnological tools in Nematology.

V. **Theory**

Unit I

Cell biology- Structural and functional aspects; genetics and evolution in plantparasitism in nematodes.

Unit II

Caenorhabditis elegans- a model system for gerontology, cytogenetics, physiology, nutritional, toxicological and pharmacological studies; *Heterodera glycines* as a model for biology, proteomic and genomic studies.

Unit III

Chemoreception, neurobiology, and biochemical basis of communication in nematodes, molecular basis of host recognition, Nematode-Associated Molecular Patterns (NAMPs), molecular pathways of plant-nematode interaction.

Unit IV

Biochemical, genetical and molecular basis of plant nematode interaction; histopathological, cellular and molecular changes in host feeding cells, resistance genes, genome editing, sequencing of genome, Transcriptome and Proteome analysis of plant parasitic nematodes, RNAi technology,

Unit V

Biochemical and molecular basis of survival strategies in nematodes, molecular mechanism of host resistance against plant parasitic nematodes, molecular and novel approaches for nematode management.

VI. **Practical**

- Isolation and quantification of proteins from nematode juveniles and eggs;
- Molecular weight determination of nematode protein;
- Buffer preparation for molecular techniques, PCR, â-esterase polymorphism in root-knot nematode;
- Nematode DNA isolation from juveniles and eggs;

- RFLP of nematode DNA;
- Nematode DNA amplification using PCR for nematode identification, RNAitechnology.

VII. Suggested Reading

- Chen ZX, Chen SY and Dickson DW. 2004. *Nematology: Advances and Perspectives. Vol. I. Nematode Morphology, Physiology and Ecology*. CABI, Wallingford.
- Fenoll C, Grundler FMW and Ohl SA. 1997. *Cellular and Molecular aspects of Plant-Nematode Relationships*. Kluwer Academic Publ., Dordrecht.
- Gommers EJ and Maas PW. 1992. *Nematology from Molecule to Ecosystem*. European Soc. of Nematologists.
- Lamberti F, Giorgi C and Bird D. 1994. *Advances in Molecular Plant Nematology*. Plenum Press.
- Perry RN and Wright DJ. 1998. *The Physiology and Biochemistry of Free-living and PlantParasitic Nematodes*. CABI, London.
- Riddle DL. 1997. *C. elegans II*. Cold Spring Harbor Press.
- Wood WB. 1988. *The Nematode Caenorhabditis elegans*. Cold Spring Harbor Press, US Zuckerman BM. 1980. *Nematodes as Biological Models*. Vols. I, II. Academic Press, New York.

I. Course Title : Plant Biosecurity and Biosafety

II. Course Code : NEMA 605

III. Credit Hours : 2+0

IV. Aim of the course

To facilitate deeper understanding of plant biosecurity and biosafety issues inagriculture.

V. Theory

Unit I

History of biosecurity, concept of biosecurity, components of biosecurity, Quarantine, Invasive Alien Species, biowarfare, emerging/ resurgence of pests and diseases.

Unit II

National Regulatory Mechanism and International Agreements/Conventions, viz., Agreement on Application of Sanitary and Phytosanitary (SPS) Measures/ World Trade Organization (WTO), Convention on Biological Diversity (CBD), International Standards for Phytosanitary Measures, pest risk analysis, risk assessment models, pest information system, early warning and forecasting system, use of Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/ disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity.

Unit III

Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, issues related to release of genetically modified crops.

VI. Suggested Reading

- Biosecurity: A Comprehensive Action Plan.Biosecurity Australia.
- Biosecurity for Agriculture and Food Production. FAO Biosecurity Toolkit 2008.
- Grotto Andrew J and Jonathan B Tucker. 2006. Biosecurity Guidance.
- Khetarpal RK and Kavita Gupta. 2006. Plant Biosecurity in India – Status and Strategy. Asian Biotechnology and Development Review 9(2): 3963.
- Randhawa GJ, Khetarpal RK, Tyagi RK and Dhillon. BS (Eds.).2001. Transgenic Crops and Biosafety Concerns. NBPGR, New Delhi.

- **e-Resources**
- http://www.inspection.gc.ca/english/anima/heasan/fad/biosecure.sht ml www.fao.org/docrep/010/a1140e/a1140e00.htm Laboratory http://www. who.int/csr/resources/publications/biosafety/WHO_CD S_EPR_2006.pdf http://www.americanprogress.org/kf/biosecurity_ a_comprehensive_ action_plan.pdf www.biosecurity.govt.nz DEFRA. www.defra.gov.uk /animalh/diseases/control/biosecurity/
- index.htm
- www.daff.gov.au/ba;www.affa.gov.au/biosecurityaustralia Biosecurity New Zealand. http://www.fao.org/biosecurity/ CFIA.

VII. List of Journals

- *Annals of Applied Nematology* – Society of Nematologists, USA
- *Current Nematology* – Bioved Research Society, Allahabad, India
- *Egyptian Journal of Agronematology* – Egyptian Society of Agricultural Nematology
- *Indian Journal of Nematology* – Nematological Society of India
- International Journal of Nematology – Afro-Asian Society of Nematologists, Luton
- *Japanese Journal of Nematology* – Japanese Nematological Society
- *Journal of Nematology* – Society of Nematologists, USA
- *Journal of Nematode Morphology and Systematics* –Jaen, Universidad de Jaen
- *Nematologia Brasiliera* – Brazilian Nematological Society

- *Nematologia Mediterranea* – Istituto per la Protezione delle Plante (IPP) – Sect. of Bari of the CNR, Italy
- *Nematology* – EJ Brill Academic Publishers, UK
- *Nematropica* – Organization of Nematologists of Tropical America
- *Pakistan Journal of Nematology* – Pakistan Society of Nematologists
- *Russian Journal of Nematology* – Russian Society of Nematologists

e-Resources

http://www.nematologists.org/ (The Society of Nematologists) http://nematology.ucdavis.edu/ (Deptt. of Nematology, Univ. of California, Davis) http://www.ifns.org/ (International Federation of Nematology Societies) http://www.inaav.ba.cnr.it/nemmed.html (Nematologia Mediterranea) http://nematode.unl.edu/Nemajob.htm (Nematology Employment Bulletin Board) http://nematode.unl.edu/ (University of Nebraska – Lincoln Nematology) http://nematode.unl.edu/wormsite.htm (Links to Other Nematology Resources) http://nematode.unl.edu/SON/jon.htm (Journal of Nematology) http://www.nematology.ucr.edu/ (Deptt. of Nematology, Univ. of California, Riverside) http://entnemdept.ifas.ufl.edu/ (Univ. of Florida, Entomology and Nematology Dept.) http://www.brill.nl/m_catalogue_sub6_id8548.htm (Nematology – journal) http://www.ars.usda.gov/main/site_main.htm?modecode=12752900 (Nematology Lab., USDA) http://flnem.ifas.ufl.edu/history/nem_history.htm (Nematology history) http://www.nematology.ugent.be/ (Nematology Unit, Ghent University) http://www.entm.purdue.edu/nematology/ (The Purdue Nematology Lab.) http://www.bspp.org.uk/ppigb/nematolo.htm#a-z (Links to Nematology labs) http://www.nem.wur.nl/UK/ (Laboratory of Nematology, Wageningen Univ.) http://onta.ifas.ufl.edu/ (The Organization of Nematologists of Tropical America)
http://www.openj-gate.org/Articlelist.asp?Source=1&Journal_ID=103267. (Nematology Newsletter)
http://nematology.umd.edu/nematology.html (Plant Nematology Laboratory, Maryland) http://www.biology.leeds.ac.uk/nem/ (Plant Nematology Lab., University of Leeds) http://www.plantpath.iastate.edu/dept/labs/tylka/ (Iowa State University, Nematology Lab) http://nematologists.org.au/newsletters.html (Australasian Association of Nematologists) http://soilplantlab.missouri.edu/nematode/ (Plant Nematology Laboratory, Missouri) http://www.eumaine.ugent.be/ (European Master of Science in Nematology) http://www.jstage.jst.go.jp/browse/jjn (The Japanese Journal of Nematology)

Suggested Broad Topics for Master's and Doctoral Research

- Identification of key nematode pests emerging in regional agro-ecosystems

- Development of molecular diagnostic tools of phytonematodes
- Nematode problems of peri-urban and protected agriculture systems, and their management
- Role of nematodes in organic matter recycling
- Modelling nematode populations for disease forecasting and predicting yield losses

FRUIT SCIENCE

Course Title with Credit Load for M.Sc. in Fruit Science		
Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
FSC 501*	Tropical Fruit Production	2+1
FSC 502*	Sub-Tropical and Temperate Fruit Production	2+1
FSC 503*	Propagation and Nursery Management of Fruit Crops	2+1
FSC 504*	Breeding of Fruit Crops	2+1
FSC 505	Systematics of Fruit Crops	2+1
FSC 506	Canopy Management of Fruit Crops	1+1
FSC 507	Growth and Development of Fruit Crops	2+1
FSC 508	Nutrition of Fruit Crops	2+1
FSC 509	Biotechnology of Fruit Crops	2+1
FSC 510	Organic Fruit Culture	2+1
FSC 511	Export Oriented Fruit Production	2+1
FSC 512	Climate Change and Fruit Crops	1+0
FSC 513	Minor Fruit Production	2+1
FSC 591	Master’s Seminar	0+1
FSC 599	Master’s Research	0+30
	Total Credits	**70**

*Compulsory among major courses

Course Title : Tropical Fruit Production

I. **Course Code : FSC 501**

II. **Credit Hours : (2+1)**

III. **Why this course ?**

Tropical fruits occupy a distinct place in global fruit production. Apart from ecological specificities, tropical fruits enjoy favour among masses being delicious and nutritious. As such, the course has been designed to provide updated knowledge on various production technologies of tropical fruits on sustainable basis.

IV. **Aim of the course**

To impart comprehensive knowledge to the students on cultural and management practices for growing tropical fruits.

The course is organised as follows:

No.	Blocks	Units
1	Introduction	Importance and Background
2	Agro-Techniques	Propagation, Planting and Orchard Floor Management
3	Crop Management	Flowering, Fruit-Set and Harvesting

V. **Theory**

Block 1: Introduction

Unit I:

Importance and Background: Importance, origin and distribution, major species, rootstocks and commercial varieties of regional, national and international importance, eco-physiological requirements.

Block 2: Agro-techniques

Unit I:

Propagation, Planting and Orchard Floor Management: Asexual and sexual methods of propagation, planting systems and planting densities, training and pruning methods, rejuvenation, intercropping, nutrient management, water management, fertigation, use of bio-fertilizers, role of bio-regulators, abiotic factors limiting fruit production.

Block 3: Crop Management

Unit I:

Flowering, Fruit-Set and Harvesting: Physiology of flowering, pollination management, fruit set and development, physiological disorders – causes and remedies, crop regulation, quality improvement by management practices; maturity indices, harvesting, grading, packing, storage and ripening techniques; insect and disease management.

Crops

Mango, Banana, Guava, Pineapple, Papaya, Avocado, Jackfruit, Annonas, Aonla, Ber, Sapota, Pomegranate etc.

VI. Practicals

- Distinguished features of tropical fruit species, cultivars and rootstocks (2);
- Demonstration of planting systems, training and pruning (3);
- Hands on practices on pollination and crop regulation (2);
- Leaf sampling and nutrient analysis (3);
- Physiological disorders-malady diagnosis (1);
- Physico-chemical analysis of fruit quality attributes (3);
- Field/ Exposure visits to tropical orchards (1);
- Project preparation for establishing commercial orchards (1).

VII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

The students are expected to equip themselves with know-how on agro-techniques for establishment and management of an orchard leading to optimum and quality fruit production of tropical fruits.

IX. Suggested Reading

- Bartholomew DP, Paull RE and Rohrbach KG. 2002. *The Pineapple: Botany, Production, and Uses.* CAB International.
- Bose TK, Mitra SK and Sanyal D. 2002. *Fruits of India – Tropical and Sub-Tropical*.3rd Edn. Naya Udyog, Kolkata.
- Dhillon WS. 2013. *Fruit Production in India.* Narendra Publ. House, New Delhi.
- Iyer CPA and Kurian RM. 2006. *High Density Planting in Tropical Fruits: Principlesand Practices.* IBDC Publishers, New Delhi.
- Litz RE. 2009. *The Mango: Botany, Production and Uses*. CAB International. Madhawa Rao VN. 2013. *Banana.* ICAR, New Delhi.
- Midmore D. 2015. *Principles of Tropical Horticulture*. CAB International. Mitra SK and Sanyal D. 2013. *Guava,* ICAR, New Delhi.

- Morton JF. 2013. *Fruits of Warm Climates.* Echo Point Book Media, USA. Nakasome HY and Paull RE. 1998. *Tropical Fruits*. CAB International. Paull RE and Duarte O. 2011. *Tropical Fruits* (Vol. 1). CAB International.
- Rani S, Sharma A and Wali VK. 2018. *Guava* (*Psidium guajava* L.). Astral, New Delhi. Robinson JC and Saúco VG. 2010. *Bananas and Plantains*. CAB International.
- Sandhu S and Gill BS. 2013. *Physiological Disorders of Fruit Crops*. NIPA, New Delhi. Schaffer B, Wolstenholme BN and Whiley AW. 2013. *The Avocado: Botany, Production and Uses.* CAB International.
- Sharma KK and Singh NP. 2011. *Soil and Orchard Management*. Daya Publishing House, New Delhi.
- Valavi SG, Peter KV and Thottappilly G. 2011. *The Jackfruit*. Stadium Press, USA.

I. **Course Title : Subtropical and Temperate Fruit Production**

II. **Course Code : FSC 502**

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

IV. **Why this course ?**

Agro-climatic diversity in India facilitates growing a wide range of fruits extending from tropical to subtropical to temperate fruits and nuts. To highlight their ecological specificities, seasonal variations and pertinent cultural practices, a course is designed exclusively for subtropical and temperate fruits.

V. **Aim of the course**

To impart comprehensive knowledge to the students on cultural and management practices for growing subtropical and temperate fruits.

The course is organised as follows:

No.	Blocks	Units
1	Introduction	Importance and Background
2	Agro-Techniques	Propagation, Planting and Orchard Floor Management
3	Crop Management	Flowering, Fruit-Set and Harvesting

VI. **Theory**

Block 1: Introduction

Unit I: Importance and Background: Origin, distribution and importance, major species, rootstocks and commercial varieties of regional, national and international importance, eco-physiological requirements.

Block 2: Agro-Techniques

Unit I: Propagation, Planting and Orchard Floor Management: Propagation, planting systems and densities, training and pruning, rejuvenation and replanting, intercropping, nutrient management, water management, fertigation, use of bio-fertilizers, role of bio-regulators, abiotic factors limiting fruit production.

Block 3: Crop Management

Unit I: Flowering, Fruit-Set and Harvesting: Physiology of flowering, pollination management, fruit set and development, physiological disorders- causes and remedies, crop regulation, quality improvement by management practices; maturity indices, harvesting, grading, packing, storage and ripening techniques; insect and disease management.

Crops

Citrus, Grapes, Litchi, Pomegranate, Apple, Pear, Peach, Plum, Apricot, Cherries, Berries, Persimmon, Kiwifruit, Strawberry, Mangosteen, Loquat, Quince etc. Nuts- Walnut, Almond, Pecan, Hazelnut.

VII. Practicals

- Distinguished features of fruit species, cultivars and rootstocks (2);
- Demonstration of planting systems, training and pruning (3);
- Hands on practices on pollination and crop regulation (2);
- Leaf sampling and nutrient analysis (3);
- Physiological disorders-malady diagnosis (1);
- Physico-chemical analysis of fruit quality attributes (3);
- Field/ Exposure visits to subtropical and temperate orchards (1);
- Project preparation for establishing commercial orchards (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the students are expected to equip themselves with principles and practices of producing subtropical (citrus, grapes, litchi, pomegranate, etc.) and temperate fruits (apple, pear, peach, plum, apricot, cherries, berries, kiwifruit, etc.) and nuts (almond, walnut, pecan, etc.)

X. **Suggested Reading**

- Chadha KL and Awasthi RP. 2005. *The Apple*. Malhotra Publishing House, New Delhi. Chadha TR. 2011. *A Text Book of Temperate Fruits*. ICAR, New Delhi
- Childers NF, Morris JR and Sibbett GS. 1995. *Modern Fruit Science: Orchard and Small Fruit Culture*. Horticultural Publications, USA.
- Creasy G and Creasy L. 2018. *Grapes.* CAB International. Davies FS and Albrigo LG. 1994. *Citrus.* CAB International.
- Dhillon WS. 2013. *Fruit Production in India.* Narendra Publishing House, New Delhi. Jackson D, Thiele G, Looney NE and Morley-Bunker M. 2011. *Temperate and Subtropical Fruit Production.* CAB International.
- Ladanyia M. 2010. *Citrus Fruit: Biology, Technology and Evaluation*. Academic Press.
- Layne DR and Bassi D. 2008. *The Peach: Botany, Production and Uses*. CABI.
- Menzel CM and Waite GK. 2005. *Litchi and Longan: Botany, Production and Uses*. CAB International.
- Pandey RM and Randey SN. 1996. *The Grape in India*. ICAR, New Delhi.
- Rajput CBS, and Haribabu RS. 2006. *Citriculture,* Kalyani Publishers, New Delhi. Sandhu S and Gill BS. 2013. *Physiological Disorders of Fruit Crops*. NIPA, New Delhi.
- Sharma RM, Pandey SN and Pandey V. 2015. *The Pear – Production, Post-harvest Management and Protection*. IBDC Publisher, New Delhi.
- Sharma RR and Krishna H. 2018. *Textbook of Temperate Fruits.* CBS Publishers and Distributors Pvt. Ltd., New Delhi.
- Singh S, Shivshankar VJ, Srivastava AK and Singh IP. 2004. *Advances in Citriculture.* NIPA, New Delhi.
- Tromp J, Webster AS and Wertheim SJ. 2005. *Fundamentals of Temperate Zone Tree Fruit Production.*Backhuys Publishers, Lieden, The Netherlands.
- Webster A and Looney N. *Cherries: Crop Physiology, Production and Uses.* CABI.
- Westwood MN. 2009. *Temperate Zone Pomology:Physiology and Culture.* Timber Press, USA.

I. **Course Title : Propagation and Nursery Management in Fruit Crops**
II. **Course Code : FSC 503**
III. **Credit Hours : (2+1)**

IV. **Why this course ?**

Availability of sufficient and healthy planting material is pivotal for expanding fruit culture. This necessitates requisite skill and efficient multiplication protocols for raising plants and their in house management prior to distributionor field transfer, hence the course is developed.

V. **Aim of the course**

To understand the principles and methods of propagation and nursery management in fruit crops.

The course is organised as follows:

No.	Blocks	Units
1	Introduction	General Concepts and Phenomena
2	Propagation	Conventional Asexual Propagation II Micropropagation
3	Nursery	Management Practices and Regulation

VI. **Theory**

Block 1: Introduction

Unit 1: General Concepts and Phenomena: Introduction, understanding cellular basis for propagation, sexual and asexual propagation, apomixis, polyembryony, chimeras. Factors influencing seed germination of fruit crops, dormancy, hormonal regulation of seed germination and seedling growth. Seed quality, treatment, packing, storage, certification and testing.

Block 2: Propagation

Unit I: Conventional Asexual Propagation: Cutting– methods, rooting of soft and hardwood cuttings under mist and hotbeds. Use of PGR in propagation, Physiological, anatomical and biochemical aspects ofroot induction in cuttings. Layering – principle and methods.

Budding and grafting – principles and methods, establishment and management of bud wood bank. Stock, scion and inter stock relationship – graft incompatibility, physiology of rootstock and top working.

Unit II: Micropropagation: Micro-propagation – principles and concepts, commercial exploitation in horticultural crops. Techniques – *in-vitro* clonal propagation, direct organogenesis, embryogenesis, micrografting, meristem culture, genetic fidelity testing. Hardening, packaging and transport of micro-propagules.

Block 3: Nursery

Unit I: Management Practices and Regulation: Nursery – types, structures, components, planning and layout. Nursery management practices for healthy propagule production. Nursery Act, nursery accreditation, import and export of seeds and planting material and quarantine.

VII. Practical

- Hands on practices on rooting of dormant and summer cuttings (3);
- Anatomical studies in rooting of cutting and graft union(1);
- Hands on practices on various methods of budding and grafting (4);
- Propagation by layering and stooling (2);
- Micropropagation- explant preparation, media preparation, culturing – meristem tip culture, axillary bud culture, micro-grafting, hardening (4);
- Visit to commercial tissue culture laboratories and accredited nurseries (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The student are expected to equip to acquire skills and knowledge on principles and practices of macro and micropropagation and the handling of propagated material in nursery.

X. Suggested Reading

- Bose TK, Mitra SK and Sadhu MK. 1991. *Propagation of Tropical and Subtropical Horticultural Crops*. Naya Prokash, Kolkatta.
- Davies FT, Geneve RL and Wilson SB. 2018. *Hartmann and Kesters Plant Propagation- Principles and Practices.* Pearson, USA/ Prentice Hall of India. New Delhi.
- Gill SS, Bal JS and Sandhu AS. 2016. *Raising Fruit Nursery*. Kalyani Publishers,New Delhi.
- Jain S and Ishil K. 2003. *Micropropagation of Woody Trees and Fruits*.

Springer.

- Jain S and Hoggmann H. 2007. *Protocols for Micropropagation of Woody Trees and Fruits*. Springer.
- Joshi P. 2015. *Nursery Management of Fruit Crops in India.* NIPA, New Delhi.
- Love *et al*. 2017. *Tropical Fruit Tree Propagation Guide.* UH-CTAHR F_N_49. College of Tropical Agriculture and Human Resources University of Hawaii at Manwa, USA.
- Peter KV, eds. 2008. *Basics of Horticulture.* New India Publishing Agency, New Delhi. Rajan S and Baby LM. 2007. *Propagation of Horticultural Crops.* NIPA, New Delhi.
- Sharma RR. 2014. *Propagation of Horticultural Crops.* Kalyani Publishers, New Delhi.
- Sharma RR and Srivastav M. 2004. *Propagation and Nursery Management.* Intl. Book Publishing Co., Lucknow.
- Singh SP. 1989. *Mist Propagation*. Metropolitan Book Co.
- Singh RS. 2014. *Propagation of Horticultural Plants: Arid and Semi-Arid Regions.* NIPA, New Delhi.
- Tyagi S. 2019. *Hi-Tech Horticulture.* Vol I: *Crop Improvement, Nursery and Rootstock Management.* NIPA, New Delhi.

I. Course Title : Breeding of Fruit Crops

II. Course Code : FSC 504

III. Credit Hours : (2+1)

IV. Why this course ?

Development of genetically improved varieties and rootstock is a continuous process which is realized through selection and breeding approaches. This is necessary to enhance the productivity and meet ever-changing climaticconditions and market/ consumer preferences. As such, a course is formulated to generate know-how on genetic and breeding aspects of fruit crops.

V. Aim of the course

To impart comprehensive knowledge on principles and practices of fruit breeding.

The course organisation is as under:

No.	Blocks	Units
1	Introduction	Importance, Taxonomy and Genetic Resources
2	Reproductive Biology	Blossom Biology and Breeding Systems
3	Breeding approaches	Conventional and Non-Conventional Breeding

VI. Theory

Block 1: Introduction

Unit I: Importance, Taxonomy and Genetic Resources: Introduction and importance, origin and distribution, taxonomical status – species and cultivars, cytogenetics, genetic resources.

Block 2: Reproductive Biology

Unit I: Blossom Biology and Breeding Systems: Blossom biology, breeding systems – spontaneous mutations, polyploidy, incompatibility, sterility, parthenocarpy, apomixis, breeding objectives, ideotypes.

Block 3: Breeding Approaches

Unit I: Conventional and Non-Conventional Breeding: Approaches for crop improvement – direct introduction, selection, hybridization, mutation breeding, polyploid breeding, rootstock breeding, improvement of quality traits, resistance breeding for biotic and abiotic stresses, biotechnological interventions, achievements and future thrusts.

Crops

Mango, Banana, Pineapple, Citrus, Grapes, Litchi, Guava, Pomegranate, Papaya, Apple, Pear, Plum, Peach, Apricot, Cherries, Strawberry, Kiwifruit, Nuts, Sapota, Jackfruit, Papaya, Custard apple, Aonla, Avocado, Mangosteen, Jamun.

VII. Practicals

- Exercises on bearing habit, floral biology (2);
- Pollen viability and fertility studies (1);
- Hands on practices in hybridization (3);
- Raising and handling of hybrid progenies (2);
- Induction of mutations and polyploidy (2);
- Evaluation of biometrical traits and quality traits (2);
- Screening for resistance against abiotic stresses (2);
- Developing breeding programme for specific traits (2);
- Visit to research stations working on fruit breeding (1).

VIII. **Teaching Methods/ Activities**

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. **Learning outcome**

After successful completion of the course, the students are expected to

- Have an understanding on importance and peculiarities of fruit breeding
- Have an updated knowledge on reproductive biology, genetics and inherent breeding systems.
- Have detailed knowledge of various methods/ approaches of breeding fruit crops

X. **Suggested Reading**

- Abraham Z. 2017. *Fruit Breeding*. Agri-Horti Press, New Delhi.
- Badenes ML and Byrne DH. 2012. *Fruit Breeding*. Springer Science, New York.
- Dinesh MR. 2015. *Fruit Breeding*, New India Publishing Agency, New Delhi.
- Ghosh SN, Verma MK and Thakur A. 2018. *Temperate Fruit Crop Breeding-Domestication to Cultivar Development.* NIPA, New Delhi.
- Hancock JF. 2008. *Temperate Fruit Crop Breeding: Germplasm to Genomics*. Springer Science, New York.
- Jain SN and Priyadarshan PM. 2009. *Breeding Plantation and Tree Crops: Tropical Species.* Springer Science, New York.
- Jain S and Priyadarshan PM. 2009. *Breeding Plantation and Tree Crops: Temperate Species* Springer Science, New York.
- Janick J and Moore JN. 1996. *Fruit Breeding*. Vols. I–III. John Wiley & Sons, USA.
- Kumar N. 2014. *Breeding of Horticultural Crops:Principles and Practices*. NIPA, N. Delhi.
- Moore JN and Janick J. 1983. *Methods in Fruit Breeding*. Purdue University Press, USA.
- Ray PK. 2002. *Breeding Tropical and Subtropical Fruits.* Narosa Publ. House, New Delhi.

I. **Course Title : Systematics of Fruit Crops**

II. **Course Code : FSC 505**

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

IV. **Why this course ?**

Life forms and their behaviour are best understood if properly described to the stake holders. Therefore, identification and characterization are pre-requisites to distinctly describe the plant species. The fruit crop species are no exception, and thus an exclusive course on their categorisation and description exhibiting a great deal of variation.

V. **Aim of the course**

To acquaint with the classification, nomenclature and description of various fruit crops.

The course is organised as under:

No.	Blocks	Units
1	Biosystematics	Nomenclature and Classification
2	Botanical Keys and Descriptors	Identification and Description
3	Special Topics	Registration and Modern Systematics

VI. **Theory**

Block 1: Biosystematics

Unit I: Nomenclature and Classification: Biosystematics – introduction and significance; history of nomenclature of cultivated plants, classification and nomenclature systems; International code of nomenclature for cultivated plants

Block 2: Botanical Keys and Descriptors

Unit I: Identification and Description: Methods of identification and description of cultivated fruit and nut species and their wild relatives features; development of plant keys for systematic identification and classification.

Development of fruit crop descriptors- based upon Bioversity International Descriptors and UPOV/ DUS test guidelines, botanical and pomological description of major cultivars and rootstocks of tropical, subtropical and temperate fruits and nut crops

Block 3: Special Topics

Unit I: Registration and Modern Systematics: Registration, Use of chemotaxonomy, biochemical and molecular markers in modern systematics

VII. **Practicals**

- Exercises on identification and pomological description of various fruit species and cultivars (6);
- Development of descriptive blanks *vis-a-vis* UPOV/ DUS test guidelines and Bioversity International (4);
- Descriptors for developing fruit species and cultivar descriptive databases (4);
- Visits to major germplasm centres and field genebanks (2).

VIII. **Teaching Methods/ Activities**

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. **Learning outcome**

After successful completion of the course, the students would be able to—

- Categorise different fruit species into broad groups.
- Identify various fruit cultivars on basis of distinguishing features
- Characterize fruit cultivars for description, registration and protection

X. **Suggested Reading**

- ASHS. 1997. *The Brooks and Olmo Register of Fruit and NutVarieties*. 3rd Ed. ASHS Press.
- Bhattacharya B and Johri BM. 2004. *Flowering Plants: Taxonomy and Phylogeny*. Narosa Pub. House, New Delhi.
- Pandey BP. 1999. *Taxonomy of Angiosperms*. S. Chand & Co. New Delhi.
- Pareek OP and Sharma S. 2017. *Systematic Pomology*. Scientific Publishers, Jodhpur.
- Sharma G, Sharma OC and Thakur BS. 2009. *Systematics of Fruit Crops*. NIPA, New Delhi.
- Simpson M. 2010. *Plant Systematics*. 2ndEdn. Elsevier.
- Spencer RR, Cross R and Lumley P. 2003. *Plant Names*. 3rd Ed. *A Guide to Botanical Nomenclature,* CISRO, Australia.
- Srivastava U, Mahajan RK, Gangopadyay KK, Singh M and Dhillon BS. 2001. *Minimal Descriptors of Agri-Horticultural Crops. I: Fruits*. NBPGR, New Delhi.
- Zielinski QB. 1955. *Modern Systematic Pomology*. Wm. C. Brown Co., Iowa, USA.

I. **Course Title : Canopy Management of Fruit Crops**

II. **Course Code : FSC 506**

III. **Credit Hours : (1+1)**

IV. **Why this course ?**

Plant architecture plays an important role in enhancing photosynthetic efficiency and resultant quantity and quality of the fruit produce. Manipulation of plant growth and development can be done by employing different training and pruning procedures besides through the use of growth regulators, specific rootstocks, etc. Hence this course is developed to address the aforesaid issues.

V. **Aim of the course**

To impart knowledge on principles and practices in management of canopy architecture for quality fruit production.

The course organisation is as follows:

No.	Blocks	Units
1	Canopy Architecture	Introduction, types and Classification
2	Canopy Management	Physical Manipulation and Growth regulation

VI. **Theory**

Block 1: Canopy Architecture

Unit I: Introduction, Types and Classification: Canopy management – importance and factors affecting canopy development. Canopy types and structures, canopy manipulation for optimum utilization of light and its interception. Spacing and utilization of land area – Canopy classification.

Block 2: Canopy Management

Unit I: Physical Manipulation and Growth Regulation: Canopy management through rootstock and scion. Canopy management through plant growth regulators, training and pruning and management practices. Canopy development and management in relation to growth, flowering, fruiting and fruit quality.

Crops

Apple, Peach, Grapes, Passion fruit, Mango, Sapota, Guava, Citrus, Jackfruit

VII. **Practicals**

- Study of different types of canopies (2);

- Training of plants for different canopy types (2);
- Canopy development through pruning (2);
- Understanding bearing behaviour and canopy management in different fruits (2);
- Use of plant growth regulators (2);
- Geometry of planting (1);
- Development of effective canopy with support system (2);
- Study on effect of different canopy types on production and quality of fruits (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the students are expected to learn

- The basic principles of canopy management to modify plant architecture
- The skills on training and pruning of fruit crops, and growth regulation

X. Suggested Reading

- Bakshi JC, Uppal DK and Khajuria HN. 1988. *The Pruning of Fruit Trees and Vines*. Kalyani Publishers, New Delhi.
- Chadha KL and Shikhamany SD. 1999. *The Grape, Improvement, Production and Post Harvest Management*. Malhotra Publishing House, Delhi.
- Iyer CPA and Kurian RM. 2006. *High Density Planting in Tropical Fruits: Principles and Practices.* IBDC Publishers, New Delhi.
- Pradeepkumar T. 2008. *Management of Horticultural Crops*. NIPA, NewDelhi.
- Singh G. 2010. *Practical Manual on Canopy Management in Fruit Crops.* Dept. of Agriculture and Co-operation, Ministry of Agriculture (GoI), New Delhi.
- Srivastava KK. 2012. *Canopy Management in Fruits*. ICAR, New Delhi

I. Course Title : Growth and Development of Fruit Crops

II. Course Code : FSC 507

III. Credit Hours : (2+1)

IV. **Why this course ?**

The underlying principles and parameters of growth and development needs to be understood for harnessing maximum benefits in term of yield and quality. External environment and inherent hormonal and metabolic pathways considerably determine growth dynamics. Thus, a course is formulated to develop know-how on physiological and physical aspects of growth and development processes.

V. **Aim of the course**

To develop comprehensive understanding on growth and development of fruit crops.

The course is structured as under:-

No.	Blocks	Units
1	Introduction	General Concepts and Principles
2	Canopy Management	Climatic Factors, Hormones and Developmental Physiology
3	Stress Management	Strategies for Overcoming Stress

VI. **Theory**

Block 1: Introduction

Unit I: General Concepts and Principles: Growth and development- definition, parameters of growth and development, growth dynamics and morphogenesis.

Block 2: Environment and Development

Unit I: Climatic Factors, Hormones and Developmental Physiology: Environmental impact on growth and development- effect of light, temperature, photosynthesis and photoperiodism, vernalisation, heat units and thermoperiodism. Assimilate partitioning, influence of water and mineral nutrition in growth and development; concepts of plant hormone and bioregulators, history, biosynthesis and physiologicalrole of auxins, gibberellins, cytokinins, abscissic acid, ethylene, growth inhibitors and retardant, brasssinosteroids, other New PGRs. Developmental physiology and biochemistry during dormancy, bud break, juvenility, vegetative to reproductive interphase, flowering, pollination, fertilization and fruit set, fruit drop, fruit growth, ripening and seed development.

Block 3: Stress Management

Unit I: Strategies for Overcoming Stress: Growth and developmental process during stress – manipulation of growth and development, impact of pruning and training, chemical manipulations and Commercial application of PGRs in fruit crops, molecular and genetic approaches in plant growth and development.

VII. Practicals

- Understanding dormancy mechanisms in fruit crops and seed stratification (2);
- Techniques of growth analysis (2);
- Evaluation of photosynthetic efficiency under different environments (2);
- Exercises on hormone assays (2);
- Practicals on use of growth regulators (2);
- Understanding ripening phenomenon in fruits (2);
- Study on impact of physical manipulations on growth and development (1);
- Study on chemical manipulations on growth and development (1);
- Understanding stress impact on growth and development (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

Consequent upon successful completion of the course, the students are expected to have

- Equipped with understanding of various growth and development processes
- Learned about the role of environment and growth substances
- Acquired the skills to realise optimum growth and development under stress conditions

X. Suggested Reading

- Bhatnagar P. 2017. *Physiology of Growth and Development of Horticultural Crops*. Agrobios (India).
- Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. John Wiley & Sons, NY, USA.
- Dhillon WS and Bhatt ZA. 2011. *Fruit Tree Physiology*. Narendra Publishing House, New Delhi.

- Durner E. 2013. *Principles of Horticultural Physiology*. CAB International.
- Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*. John Wiley & Sons, NY, USA.
- Faust M. 1989. *Physiology of Temperate Zone Fruit Trees*. John Willey & Sons, NY, USA.
- Fosket DE. 1994. *Plant Growth and Development: a*
- *Molecular Approach*. Academic Press, USA. Leopold AC and Kriedermann PE. 1985. *Plant Growth and Development*. 3rd Ed. McGraw-Hill, New Delhi.
- Roberts J, Downs S and Parker P. 2002. Plant Growth Development. In: Salisbury FB and Ross CW. (Eds.) *Plant Physiology*. 4th Ed.Wadsworth Publications, USA.
- Schafeer, B. and Anderson, P. 1994. *Handbook of EnvironmentalPhysiology of Fruit Crops*. Vol. 1 & 2. CRC Press. USA.
- Seymour GB, Taylor JE and Tucker GA. 1993. *Biochemistry of Fruit Ripening*. Chapman & Hall, London.

I. **Course Title : Nutrition of Fruit Crops**

II. **Course Code : FSC 508**

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

IV. **Why this course ?**

Nutrients play a significant role in almost every growth and development process determining vigour, yield and quality of fruits. Henceforth, a course is designed to have an in depth study of various nutrients, their uptake and use efficiency in realizing sustainable fruit production

V. **Aim of the course**

To acquaint with principles and practices involved in nutrition of fruit crops The course is organised as under:-

No.	Blocks	Units
1	Introduction	General Concepts and Principles
2	Requirements and Applications	Diagnostics, Estimation and Application
3	Newer Approaches	Integrated Nutrient Management (INM

VI. **Theory**

Block 1: Introduction

Unit I: General Concepts and Principles: Importance and history of nutritionin fruit crops, essential plant nutrients, factors affecting plant nutrition; nutrient uptake and their removal from soil.

Block 2: Requirements and Applications

Unit I: Diagnostics, Estimation and Application: Nutrient requirements, root distribution in fruit crops, soil and foliar application of nutrients in major fruit crops, fertilizer use efficiency. Methods and techniques for evaluating the requirement of macro- and micro-elements, Diagnostic and interpretation techniques including DRIS. Role of different macro- and micro-nutrients, their deficiency and toxicity disorders, corrective measures to overcome deficiency and toxicity disorders.

Block 3: Newer Approaches

Unit I: Integrated Nutrient Management (INM): Fertigation in fruit crops, bio-fertilizers and their use in INM systems.

VII. Practicals

- Visual identification of nutrient deficiency symptoms in fruit crops (2);
- Identification and application of organic, inorganic and bio-fertilizers (1);
- Soil/ tissue collection and preparation for macro- and micro-nutrient analysis (1);
- Analysis of soil physical and chemical properties- pH, EC, Organic carbon (1);
- Determination of N,P,K and other macro- and micronutrients (6);
- Fertigation in glasshouse and field grown horticultural crops (2);
- Preparation of micro-nutrient solutions, their spray and soil applications (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After successful completion of the course, the students would be expected to

- Know the importance and various types of nutrients and their uptake mechanisms
- Analyse soil and plant status with respect to various nutrients
- Make use of corrective measures to overcome deficiency or toxicity

X. Suggested Reading

– Atkinson D, Jackson JE and Sharples RO. 1980. *Mineral Nutrition of Fruit Trees.* Butterworth Heinemann.

- Bould C, Hewitt EJ and Needham P. 1983. *Diagnosis of Mineral Disorders in Plants Vol.1 Principles.* Her Majesty's Stationery Office, London.
- Cooke GW. 1972. *Fertilizers for maximizing yield*. Grenada Publishing Ltd, London.
- Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*. Wiley Eastern Ltd. Kanwar JS. 1976. *Soil Fertility-Theory and Practice*. ICAR, New Delhi.
- Marchner Horst. 1995. *Mineral Nutrition of Higher Plants*, 2nd Ed. Marschner, Academic Press Inc. San Diego, CA.
- Mengel K and Kirkby EA. 1987. *Principles of Plant Nutrition*. 4th Ed. International Potash Institute, Worblaufen-Bern, Switzerland.
- Prakash M. 2013. *Nutritional Disorders in Fruit Crops: Diagnosis and Management*. NIPA, New Delhi.
- Tandon HLS. 1992. *Management of Nutrient Interactions in Agriculture*. Fertilizer Development and Consultation Organization, New Delhi.
- Westerman RL. 1990. *Soil Testing and Plant Analysis*, 3rd Ed. Soil Science Society of America, Inc., Madison, WI.
- Yawalkar KS, Agarwal JP and Bokde S. 1972. *Manures and Fertilizers*. 3rd Ed. Agri Horticultural Publishing House, Nagpur.

I. **Course Title : Biotechnology of Fruit Crops**

II. **Course Code : FSC 509**

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

IV. **Why this course ?**

In the recent times, biotechnological interventions in fruit crops have contributed in enhanced yield, biotic and abiotic stress management and improved quality traits to a considerable extent. Hence, a course is designed to educate on the possibilities and progress made through biotechnology for improved fruit production.

V. **Aim of the course**

To impart knowledge on the principles and tools of biotechnology.

Structure of the course is as under:

No.	Blocks	Units
1	General Background	Introduction, History and Basic Principles
2	Tissue Culture	*In-vitro* Culture and Hardening
3	Genetic Manipulation	*In-vitro* Breeding, Transgenics and Gene Technologies

VI. **Theory**

Block 1: General Background

Unit I: Introduction, History and Basic Principles: Introduction and significance, history and basic principles, influence of explant material, physical, chemical factors and growth regulators on growth and development of plant cell, tissue and organ culture.

Block 2: Tissue Culture

Unit I: *In-vitro* Culture and Hardening: Callus culture – types, cell division, differentiation, morphogenesis, organogenesis, embryogenesis; Organ culture – meristem, embryo, anther, ovule culture, embryo rescue, somaclonal variation, protoplast culture. Use of bioreactors and *in-vitro* methods for production of secondary metabolites, suspension culture, nutrition of tissues and cells, regeneration of tissues.Hardening and *ex vitro* establishment of tissue cultured plants.

Block 3: Genetic Manipulation

Unit I: *In-vitro* Breeding, Transgenics and Gene Technologies: Somatic cell hybridisation, construction and identification of somatic hybrids and cybrids, wide hybridization, *in-vitro* pollination and fertilization, haploids, *in-vitro* mutation, artificial seeds, cryopreservation, *In-vitro* selection for biotic and abiotic stress. Genetic engineering- principles and methods, transgenics in fruit crops, use of molecular markers and genomics. Gene silencing, gene tagging, gene editing, achievements of biotechnology in fruit crops.

VII. **Practicals**

- An exposure to low cost, commercial and homestead tissue culture laboratories (2);
- Media preparation, Inoculation of explants for clonal propagation, callus induction and culture, regeneration of plantlets from callus (3);
- Sub-culturing techniques on anther, ovule, embryo culture, somaclonal variation (4);
- *In-vitro* mutant selection against abiotic stress (2);
- Protoplast culture and fusion technique (2);
- Development of protocols for mass multiplication (2);

- Project development for establishment of commercial tissue culture laboratory (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

After the successful completion of the course, the students are expected to know

- Basic principles and methods of plant tissue culture and other biotechnological tools.
- The use and progress of biotechnology in fruit crops.

X. Suggested Reading

- Bajaj YPS. Eds., 1989. *Biotechnology in Agriculture and Forestry*. Vol. V, *Fruits*. Springer, USA.
- Brown TA. 2001. *Gene Cloning and DNA Analysis and Introduction.* Blackwell Publishing, USA.
- Chahal GS and Gosal SS. 2010. *Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches*. Narosa, New Delhi.
- Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology – Concepts, Methods and Applications.* Oxford & IBH, New Delhi.
- Kale C. 2013. Genome Mapping and Molecular Breeding in Plant, Vol 4. *Fruit and Nuts* Springers.
- Keshavachandran R and Peter KV. 2008. *Plant Biotechnology: Tissue Culture and Gene Transfer* Orient & Longman, Universal Press, US.
- Keshavachandran R, Nazeem PA, Girija D, John PS and Peter KV. 2007. *Recent Trends in Biotechnology of Horticultural Crops*. Vols. I, II. NIPA, New Delhi.
- Litz RE. 2005. *Biotechnology of Fruit and Nut Crops.* CABI, UK.
- Miglani GS. 2016. *Genetic Engineering – Principles, Procedures and Consequences*. Narosa Publishing House, New Delhi.
- Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK and Mohanadas S. 2001. *Biotechnology of Horticultural Crops*. Vols. I–III. Naya Prokash, Kolkata.

- Peter KV. 2013. *Biotechnology in Horticulture: Methods and Applications*. NIPA, New Delhi. Vasil TK, Vasi M, While DNR and Bery HR. 1979. *Somatic Hybridization and Genetic Manipulation in Plants. Plant Regulation and World Agriculture*. Platinum Press, UK.

I. **Course Title : Organic Fruit Culture**

II. **Course Code : FSC 510**

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

IV. **Why this course ?**

Considering threats to environment and human health on account of excessive use of chemicals and synthetic fertilizers, organic farming is looked upon as an alternative. Though the organic and other natural farming practices are in evolving phase and are yet to be time scale tested, there is a general perception that these would hold good. As such a course is customised to educate the Graduates on various issues related to organic farming.

V. **Aim of the course**

To develop understanding on organic production of fruit crops.

The course is structured as under:-

No.	Blocks	Units
1	General Aspects	Principles and Current Scenario
2	Organic Culture	Farming System and Practices
3	Certification	Inspection, Control Measures and Certification

VI. **Theory**

Block 1: General Aspects

Unit I: Principles and Current Scenario: Organic horticulture, scope, area, production and world trade, definition, principles, methods and SWOT analysis.

Block 2: Organic Culture

Unit I: Farming System and Practices: Organic farming systems including biodynamic farming, natural farming, homa organic farming, rishi krishi, EM technology, cosmic farming; on-farm and off-farm production of organic inputs, role of bio-fertilizers, bio enhancers, legumes, inter cropping, cover crops, green manuring, zero tillage, mulching and their role in organic nutrition management. Organic seeds and planting materials, soil health management in organic production, weed management practices in organic farming, biological management of pests and diseases, trap crops, quality improvement in organic production of fruit crops, bacterial consortiums and other organic formulations used as bio stimulants from national institutes.

Block 3: Certification

Unit I: Inspection, Control Measures and Certification: Inspection and certification of organic produce, participatory guarantee system (PGS), NPOP, documentation and control, development of internal control system (ICS), Concept of group certification, constitution of grower group as per NPOP, preparation of ICS manual, internal and external inspection, concept of third party verification, certification of small farmer groups (Group Certification), transaction certificate, group certificate, critical control points (CCP) and HACCP, IFOAM guidelines on certification scope and chain of custody, certification trademark – The Logo, accredited certification bodies under NPOP. Constraints in certification, IFOAM and global scenario of organic movement, postharvest management of organic produce. Economics of organic fruit production.

VII. Practicals

- Design of organic orchards/ farms management (1);
- Conversion plan (1);
- Nutrient management and microbial assessment of composts and bio-enhancers (2);
- Preparation and application of composts, bio-enhancers and bio-pesticides (2);
- Organic nursery raising (1);
- Application of composts, bio-enhancers, bio-fertilisers and bio-pesticides, green manure, cover, mulching (2);
- Preparation and use of neem based products (1);
- Biodynamic preparations and their role in organic agriculture, EM technology and products, biological/ natural management of pests and diseases (2);
- Soil solarisation (1);
- Frame work for GAP (1);
- Documentation for certification (1).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals

- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

On successful completion of the course, the students are expected to be able to

- Familiarize with the concepts and practices of organic and other natural farming systems
- Generate know-how on procedures, policies and regulation for inspection and certification of organic produce

X. Suggested Reading

- Claude A. 2004. *The Organic Farming Sourcebook*. Other India Press, Mapusa, Goa, India.
- Dabholkar SA. 2001. *Plenty for All.* Mehta Publishing House, Pune, Maharashtra.
- Das HC and Yadav AK. 2018. *Advances in Organic Production of Fruit Crops.* Westville Publishing House, New Delhi.
- Deshpande MS. 2003. *Organic Farming with respect to Cosmic Farming.* Mrs. Pushpa Mohan Deshpandey, Kolhapur, Maharashtra.
- Deshpande WR. 2009. *Basics of Organic Farming*. All India Biodynamic and Organic Farming Association, Indore. MP.
- Gaur AC, Neblakantan S and Dargan KS. 1984 *Organic Manures*. ICAR, New Delhi. Lampkin, N. and Ipswich, S. 1990. *Organic Farming*. Farming Press. London, UK.
- Lind K, Lafer G, Schloffer K, Innershofer G and Meister H. 2003. *Organic Fruit Growing.* CAB International.
- Palaniappan SP and Annadurai K. 2008. *Organic Farming- Theory and Practice*. Scientific Publishers, Jodhpur, Rajasthan, India.
- Palekar S. 2004. *The Technique of Spritual Farming*. Chandra Smaritee, Sai Nagar, Amrawati, Maharashtra.
- Proctor P. 2008. Biodynamic Farming and Gardening. Other India Press, Mapusa, Goa.
- Ram RA and Pathak RK. 2017. Bioenhancers. Lap Lambert Academic Publishing, AP.

I. Course Title : Export Oriented Fruit Production

II. Course Code : FSC 511

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

IV. **Why this course ?**

India is a top ranking country in production of fruit crops especially with respect mangoes, bananas, and grapes. WTO regime opens new vistas for exploring export opportunities of different fruit commodities. Already, India exports mangoes, litchi, grapes, walnuts, apples, etc. and there lies a huge potential in this sector. As such a course has been developed to highlight government policies, standards, infrastructural development and export potential vis-à-vis international scenario.

V. Aim of the course

To acquaint with the national and international standards and export potential of fruit crops

The course is organised as under:-

No.	Blocks	Units
1	Introduction	Statistics and World Trade
2	Regulations	Policies, Norms and Standards
3	Quality Assurance	Infrastructure and Plant Material

VI. **Theory**

Block 1: Introduction

Unit I: Statistics and World Trade: National and international fruit export and import scenario and trends; Statistics and India's position and potentiality in world trade; export promotion zones in India. Government Policies.

Block 2: Regulations

Unit I: Policies, Norms and Standards: Scope, produce specifications, quality and safety standards for export of fruits, viz., mango, banana, grape, litchi, pomegranate, walnut, apple and other important fruits. Processed and value-added products, post harvest management for export including packaging and cool chain; HACCP, Codex alimentarius, ISO certification; WTO and its implications, sanitary and phyto-sanitary measures.

Block 3: Quality Assurance

Unit I: Infrastructure and Plant Material: Quality fruit production under protected environment; different types of structures – Automated greenhouses, glasshouse, shade net, poly tunnels – Design and development of low cost greenhouse structures. Seed and planting material; meeting export standards, implications of plant variety protection – patent regimes.

VII. Practicals

- Export promotion zones and export scenario of fresh fruits and their products (1);
- Practical exercises on quality standards of fruits for export purpose (2);
- Quality standards of planting material and seeds (2);
- Hi-tech nursery in fruits (1);
- Practicals on ISO specifications and HACCP for export of fruits (3);
- Sanitary and phyto-sanitary measures during export of horticultural produce (2);
- Post harvest management chain of horticultural produce for exports (2);
- Visit to export oriented units/ agencies like APEDA, NHB, etc.

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

Consequent upon successful completion of the course, the students are expected to have learnt about

- National and international trade scenario of fruit crops
- Set norms and standards for export of fruit crops
- Requisite infrastructure and growing practices meeting export standards

X. Suggested Reading

- Chadha KL. 1995. *Advances in Horticulture.* Vol. XII. Malhotra Publ. House, New Delhi.
- Chetan GF. 2015. *Export Prospects of Fruits and Vegetables from India: A study of Export market in EU. A project report*. Anand Agricultural University, Anand, Gujarat.
- Dattatreylul M. 1997. *Export potential of Fruits, Vegetables and Flowers from India*. NABARD, Mumbai.
- Islam, C.N. 1990. *Horticultural Export of Developing Countries: Past Preferences, Future Prospects and Policies*. International Institute of Food Policy Research, USA.

e-Resources http://apeda.gov.in http://nhb.gov.in http://indiastat.com

I. Course Title : Climate Change and Fruit Crops

II. Course Code : FSC 512

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

IV. **Why this course ?**

In the changing climatic scenario, the fruit crops get affected adversely due to one or more unfavourable environmental factors. Shifting of temperate fruits to higher altitudes due to insufficient chilling, occurrence of drought and frost in warmer areas are notable examples. In order to educate on extent of damage and strategies to mitigate the effect of climate change, a course has beenformulated.

V. **Aim of the course**

To understand the impact of climate change and its management in fruit production. The course is structured as under:-

No.	Blocks	Units
1	General Aspects	Introduction, Global Warming and Climatic Variability
2	Climate Change and Management	Impact Assessment and Mitigation
3	Case Studies	Response to Climate Change

VI. **Theory**

Block 1: **General Aspects**

Unit I: Introduction, Global Warming and Climatic Variability: Introduction to climate change. Factors directly affecting climate change. Global warming, effect of climate change on spatio-temporal patterns of temperature and rainfall, concentrations of greenhouse gasses in atmosphere. pollution levels such as tropospheric ozone, change in climatic variability and extreme events.

Block 2: **Climate Change and Management**

Unit I: Impact Assessment and Mitigation: Sensors for recording climatic parameters, plants response to the climate changes, premature bloom, marginally overwintering or inadequate winter chilling hours, longer growing seasons and shifts in plant hardiness for fruit crops.

Climate mitigation measures through crop management- use of tolerant rootstocks and varieties, mulching – use of plastic- windbreak- spectral changes- protection from frost and heat waves. Climate management in greenhouse- heating – vents – CO_2 injection –screens – artificial light. Impact of climate changes on invasive insect,disease, weed, fruit yield, quality and sustainability. Climate management for control of pests, diseases, quality, elongation of growth and other plant processes- closed production systems.

Block 3: **Case Studies**

Unit I: Response to Climate Change: Case studies – responses of fruit trees to climatic variability *vis-a-vis* tolerance and adaptation; role of fruit trees in carbon sequestration.

VII. **Teaching Methods/ Activities**

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. **Learning outcome**

After the successful completion of the course, the students are expected to have learnt

- Nature and extent of altered behaviour or damage due to climate change
- Methods to assess the adverse effects
- Approaches to mitigate the effect due to climatic variability

IX. **Suggested Reading**

- Dhillon WS and Aulakh PS. 2011. *Impact of Climate Change in Fruit Production*. Narendra Publishing House, New Delhi.
- Peter KV. 2008. *Basics in Horticulture*. New India Publishing Agency, New Delhi.
- Ramirez F and Kallarackal J. 2015. *Responses of Fruit Trees to Global Climate Change*. Spinger- Verlag.
- Rao GSLHV. 2008. *Agricultural Meteorology*. Prentice Hall, New Delhi.
- Rao GSLHV, Rao GGSN, Rao VUM and Ramakrishnan YS. 2008. *Climate Change and Agriculture over India*. ICAR, New Delhi.
- Schafeer B and Anderson P. 1994. *Handbook of Environmental Physiology of Fruit Crops*.Vol. & 2. CRC Press. USA.

I. **Course Title** **: Minor Fruit Production**

II. **Course Code** **: FSC 513**

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

IV. **Why this course ?**

Apart from commercially grown fruits, several other fruits inspite of being rich in nutrients and potential future crops, remains neglected/ underexploited. The hardy nature coupled with the possibility of diversification (newly domesticated crops) further adds to their importance. The course outlines the efforts made in standardizing agro-techniques for propagation and cultivation besides know-how on their nutraceutical value and other uses.

V. Aim of the course

To import basic knowledge about underexploited minor fruit crops. The course is structured as under:-

No.	Blocks	Units
1	Introduction	Occurrence, Adoption and General Account
2	Agro-Techniques	Propagation and Cultural Practices
3	Marketing and utilization	Post-Harvest Management

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VI. Learning outcome

On successful completion of the course, the students are expected to know about

- Various minor fruits hitherto neglected and their commercial value
- Efforts made to domesticate minor fruits and standardization of agro-techniques.
- Their utilization in processing industry.

VII. Theory

Block 1: Introduction

Unit I: Occurrence, Adoption and General Account: Importance – occurrence and distribution, climate adaptation in fragile ecosystem and wastelands.

Block 2: Agro-Techniques

Unit I: Propagation and Cultural Practices: Traditional cultural practices and recent development in agro-techniques; propagation, botany-floral biology, growth patterns, mode of pollination, fruit set, ripening, fruit quality.

Block 3: Marketing and Utilization

Unit I: Post-Harvest Management: Post harvest management, marketing; minor fruit crops in terms of medicinal and antioxidant values; their uses for edible purpose and in processing industry

Crops

Bael, chironji, fig, passion fruit, jamun, phalsa, karonda, woodapple, cactus pear, khejri, kair, pilu, lasoda, loquat, tamarind, dragon fruit, monkey jack, mahua, khirni, amra, kokum, cape gooseberry, kaphal, persimmon, pistachio, seabuckthorn, hazel nut and other minor fruits of regional importance

VIII. Practicals

- Visits to institutes located in the hot and cold arid regions of the country (2);
- Identification of minor fruits plants/ cultivars (2);
- Collection of leaves and preparation of herbarium (1);
- Allelopathic studies (2);
- Generating know-how on reproductive biology of minor fruits (4);
- Fruit quality attributes and biochemical analysis (3);
- Project formulation for establishing commercial orchards in fragile ecosystems (1).

IX. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

X. Suggested Reading

- Ghosh SN, Singh A and Thakur A. 2017. *Underutilized Fruit Crops: Importance and Cultivation* Jaya Publication House, New Delhi.
- Krishna H and Sharma RR, 2017. *Fruit Production: Minor Fruits*. Daya Publishing House, New Delhi.
- Mazumdar BC. 2014. *Minor Fruit Crops of India: Tropical and Subtropical*. Daya Publication House, New Delhi.
- Nath V, Kumar D, Pandey V and Pandey D. 2008. *Fruits for the Future*. Satish Serial Publishing House, New Delhi.
- Pareek OP, Sharma S, and Arora RK. 2007. *Underutilised Edible Fruits and Nuts*, IPGRI, Rome.
- Peter KV. 2010. *Underutilized and Underexploited Horticultural Crops*. NIPA, New Delhi.
- Rana JC and Verma VD. 2011. *Genetic Resources of Temperate Minor Fruit* (*Indigenous and Exotic*). NBPGR, New Delhi.
- Saroj PL and Awasthi OP. 2005. *Advances in Arid Horticulture*, Vol. II: *Production Technology of Arid and Semiarid Fruits*. IBDC, Lucknow.
- Saroj PL, Dhandar DG and Vashishta BB. 2004. *Advances in Arid Horticulture*, Vol.-1 *Present Status*. IBDC, Lucknow.
- Singh *et al*. 2011. *Jamun*. ICAR, New Delhi.

Course Title with Credit Load for Ph.D in Fruit Science

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
FSC 601*	Innovative Approaches in Fruit Breeding	3+0
FSC 602*	Modern Trends in Fruit Production	3+0
FSC 603	Recent Developments in Growth Regulation	3+0
FSC 604	Advanced Laboratory Techniques	1+2
FSC 605	Arid and Dry Land Fruit Production	2+0
FSC 606	Abiotic Stress Management in Fruit Crops	2+1
FSC 607	Biodiversity and Conservation of Fruit Crops	2+1
FSC 608	Smart Fruit Production	2+0
	Minor courses	06
	Supporting courses	05
FSC 691	Doctoral Seminar - I	0+1
FSC 692	Doctoral Seminar - II	0+1
FSC 699	Doctoral Research	0+75
	Total Credits	**100**

*Compulsory among major courses

I. **Course Title : Innovative Approaches in Fruit Breeding**

II. **Course Code : FSC 601**

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

IV. **Why this course ?**

Modern day fruit culture witnesses rapid changes in production technologies and market trends. Ever changing environment and consumer preferences warrant constant development and adoption of genetically improved varieties.There is more thrust on novelty and distinctness in view of ever increasing competition with enhanced emphasis on tailor made and trait specific designer varieties and rootstocks. The course is thus designed to integrate updated information on inherent breeding systems and innovative gene manipulation technologies enhancingbreedingefficiency.

V. **Aim of the course**

To update knowledge on current trends and innovative approaches in fruit breeding. The structural organisation of the course is as under:-

No.	Blocks	Units
1	Introduction	Current Trends and Status
2	Genetic Mechanisms	Inheritance Patterns and Breeding Systems
3	Breeding for Specific Traits	Plant Architecture, Stress Tolerance and Fruit Quality
4	Fast-Track Breeding	Transgenics, Markers and Genomics

VI. **Theory**

Block 1: Introduction

Unit I: Current Trends and Status: Modern trends in fruit breeding –with major emphasis on precocity, low tree volume, suitability for mechanization, health benefits, etc.

Block 2: **Genetic Mechanisms**

Unit I: Inheritance Patterns and Breeding Systems: Genetics of important traits and their inheritance pattern, variations and natural selection, spontaneous mutations, incompatibility systems in fruits.

Block 3: Breeding for Specific Traits

Unit I: Plant Architecture, Stress Tolerance and Fruit Quality: Recent advancesin crop improvement efforts- wider adaptation, plant architecture, amenability to mechanization, fruit quality attributes, stress tolerance, crop specific traits; use of apomixis, gene introgression and wide hybridization (alien genes).

Block 4: Fast-Track Breeding

Unit I: Transgenics, Markers and Genomics: Molecular and transgenic approaches in improvement of selected fruit crops; fast track breeding – marker assisted selection and breeding (MAS and MAB), use of genomics and gene editing tehnologies.

Crops

Mango, banana, guava, papaya, Citrus, grapes, pomegranate, litchi, apple, pear, strawberry, plums, peaches, apricot, cherries, nut crops, Sapota, Pineapple and Avocado.

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

On successful completion of the course, the students are expected to

- Develop updated knowledge on current breeding objectives and trends
- Equip with information on innovative approaches enhancing breeding efficiency

IX. Suggested Reading

- Al-Khayari J, Jain SN and Johnson DV. 2018. *Advances in Plant Breeding Strategies. Vol. 3: Fruits.* Springer.
- Badenes S and Byrne DH. 2012. *Fruit Breeding*. Springer.
- Dinesh, M R , 2015. Fruit Breeding. New India Publishing Agency, New Delhi 352p.
- Hancock JF. 2008. *Temperate Fruit Crop Breeding: Germplasm to Genomics*. Springer.
- Kole C and Abbott AG. 2012. *Genetics, Genomics and Breeding of Stone fruits.* CRC.
- Kole, C. 2011. *Wild Crops Relatives: Genomics and Breeding Resources: Tropical and Subtropical Fruits.* Springer-Verlag.
- Kole C. 2011. *Wild Crops Relatives: Genomics and Breeding Resource: Temperate Fruits.* Springer -Verlag.
- Jain SN and Priyadarshan PM. 2009. *Breeding Plantation and Tree Crops: Tropical Species*; *Temperate Species*. Springer -Verlag.
- Janick J and Moore JN, 1996. *Fruit Breeding*. Vols.I-III. John Wiley & Sons, USA. Orton T. 2019. *Methods in Fruit Breeding*. Elsevier.
- Singh SK, Patel VB, Goswami AK, Prakash J and Kumar C. 2019. *Breeding of Perennial Horticultural Crops*. Biotech Books. Delhi.

I. **Course Title : Modern Trends in Fruit Production**

II. **Course Code : FSC 602**

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

IV. **Why this course ?**

Recent technological developments in propagation and cultural practices paves the way to grow fruit crops in an intensive and mechanised mode. As such a course has been developed to provide latest knowledge and updated account of modern production systems enhancing overall productivity.

V. **Aim of the course**

To keep abreast with latest developments and trends in production technologies of tropical, subtropical and temperate fruits.

The course structure is as follows:-

No.	Blocks	Units
1	Introduction	General Concepts and Current Scenario
2	Advanced Technologies	Propagation, Planting Systems and Crop Regulation
3	Management Practices	Overcoming Stress and Integrated Approaches

VI. **Theory**

Block 1: Introduction

Unit I: General Concepts and Current Scenario: National and International scenario, national problems.

Block 2: Advanced Technologies

Unit I: Propagation, Planting Systems and Crop Regulation: Recent advances in propagation – root stocks, planting systems, High density planting, crop modeling, Precision farming, decision support systems – aspects of crop regulation- physical and chemical regulation.

Block 3: Management Practices

Unit I: Overcoming Stress and Integrated Approaches: Effects on physiology and development, influence of stress factors, strategies to overcome stress effects, integrated and modern approaches in water and nutrient management, Physiological disorders, Total quality management (TQM) – Current topics.

Crops

Mango, Banana, Grapes, Citrus, Papaya, Litchi, Guava, Pomegranate, Apple, Pear, Peach, Plum, Apricot, Cherry, Almond, Strawberry, Kiwifruit, Sapota, Aonla, Pineapple, Avocado, Jackfruit

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

After the successful completion of the course, the students would have

- Updated knowledge on current trends in fruit production.

IX. Suggested Reading

- Bartholomew DP, Paull RE and Rohrbach KG. eds. 2002. *The Pineapple: Botany, Production, and Uses.* CAB International.
- Bose TK, Mitra SK and Sanyol D. Eds. 2002. *Fruits of India – Tropical and Sub- Tropical*. 3rd Ed. Vols. I, II. Naya Udyog, Kolkata, India.
- Dhillon WS and Bhatt ZA. 2011. *Fruit Tree Physiology*. Narendra Publishing House, New Delhi. Dhillon WS. 2013. *Fruit Production in India*. Narendra Publishing House, New Delhi.
- Gowen S. 1995. *Bananas and Plantains*. Chapman & Hall Publication, US.
- Litz RE. ed. 2009. *The Mango: Botany, Production and Uses*. CAB International. Peter KV. 2016. *Innovations in Horticulture*. NIPA, NewDelhi.
- Robinson JC and Saúco VG. 2010. *Bananas and Plantains* (Vol. 19). CAB International. Samson JA. 1980. *Tropical Fruits*. Longman, USA.
- Sharma RR and Krishna H. 2014. *Fruit Production: Major Fruits*. Daya Publishing House, Delhi.
- Singh S, Shivankar VJ, Srivastava AK and Singh IP. 2004. *Advances in Citriculture*. Jagmander Book Agency, New Delhi.
- Stover RH and Simmonds NW. 1991. *Bananas*. Longman, USA.
- Chadha KL, Ahmed N, Singh SK and Kalia P. 2016. *Temperate Fruits and Nuts- Way Forward for Enhancing Production and Quality.*Daya Publishing House, New Delhi.

- Childers NF, Morris JR and Sibbett GS. 1995. *Modern Fruit Science: Orchard and Small Fruit Culture.* Horticultural Publications, USA.
- Erez A. 2013. *Temperate Fruit Crops in Warm Climates*. Springer Science.
- Jackson D, Thiele G, Looney NE and Morley-Bunker M. 2011. *Temperate and Subtropical Fruit Production.* CAB International.
- Ryugo K. 1998. *Fruit Culture: Its Science and Art.* John Wiley & Sons, USA.
- Tromp J, Webster AS and Wertheim SJ. 2005. *Fundamentals of Temperate Zone Tree Fruit Production. Backhuys Publishers,* Lieden, The Netherlands.
- Westwood MN. 2009. *Temperate Zone Pomology: Physiology and Culture.* 3rd Edn. Timber Press, USA.
- Sau, S and Datta, P 2018, Advanced Fruit Science. Kalyani Publishers, Ludhiana, 190 A.

I. **Course Title : Recent Developments in Growth Regulation**

II. **Course Code : FSC 603**

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

IV. **Why this course ?**

Technological advancements have resulted in deeper understanding of growth and developmental processes in plants. There is equal and just need to applythese in fruit crops for harnessing maximum benefits in term of yield and quality.So a course has been designed to provide latest information on physiological and biochemical aspects of growth and development.

V. **Aim of the course**

To develop updates on recent advances in growth regulation of fruit crops. Structure of the course is as under:

No.	Blocks	Units
1	Introduction	Current Concepts and Principles
2	Growth Substances	Phytohormones and Growth Regulators
3	Growth and Development	Regulation of Developmental Processes

VI. **Theory**

Block 1: Introduction

Unit I: Current Concepts and Principles: Eco-physiological influences on growth and development of fruit crops-flowering, fruit set- Crop load and assimilate partitioning and distribution.

Block 2: Growth Substances

Unit I: Phytohormones and Growth Regulators: Root and canopy regulation, study of plant growth regulators in fruit culture- structure, biosynthesis, metabolic and morphogenetic effects of different plant growth promoters and growth retardants. Absorption, translocation and degradation of phytohormones – internal and external factors influencing hormonal synthesis, biochemical action, growth promotion and inhibition, canopy management for fertigated orchards.

Block 3: Growth and Development

Unit I: Regulation of Developmental Processes: Growth regulation aspects of propagation, embryogenesis, seed and bud dormancy, fruit bud initiation, regulation of flowering, off season production.

Flower drop and thinning, fruit-set and development, fruit drop, parthenocarpy, fruit maturity and ripening and storage, molecular approaches in crop growth regulation- current topics.

VII. Teaching Methods/ Activities

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. Learning outcome

After the successful completion of the course, the students would have

- Complete understanding of growth dynamics in various fruit crops
- Know-how on manipulation of growth and development processes.

IX. Suggested Reading

- Bhatnagar P. 2017. *Physiology of Growth and Development of Horticultural Crops.* Agrobios (India).
- Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. John Wiley & Sons, US.
- Fosket DE. 1994. *Plant Growth and Development: A Molecular Approach*. Academic Press, USA.
- Leopold AC and Kriedermann PE. 1985. *Plant Growth and Development*. 3rd Ed. McGraw-Hill, US.
- Richard N. Arteca. 1995. *Plant Growth Substances – Principles and*

Applications. Chapman & Hall, USA.

- Roberts J, Downs S and Parker P. 2002. *Plant Growth Development*. In: *Plants* (I. Ridge, Ed.), Oxford University Press.
- Salisbury FB and Ross CW. 1992. *Plant Physiology*. 4th Ed. Wadsworth Publication.

I. Course Title : Advanced Laboratory Techniques

II. Course Code : FSC 604

III. Credit Hours : (1+2)

IV. Why this course ?

Accurate quality analysis of edible fruit commodities warrants stringent measurement protocols besides requisite instruments/ tools and laboratory facilities. Consequently, a specialised course is designed for imparting basic and applied training on physical and biochemical assessment of the horticultural produce.

V. Aim of the course

To familiarize with the laboratory techniques for analysis of fruit crops.

The organisation of the course is as under:-

No.	Blocks	Units
1	General Aspects	1. Safety Measures and Laboratory Maintenance
2	Qualitative and Quantitative	1 Destructive and Non-destructive Analysis Analysis
3	Growth and Development	II Chromatographic and microscopic Analysis III Sensory Analysis

VI. Theory

Block 1: General Aspects

Unit 1: Safety Measures and Laboratory Maintenance: Safety aspects and upkeep of laboratory, sampling procedures for quantitative analysis, determination of proximate composition of horticultural produce. Standard solutions, determination of relative water content (RWC), physiological loss in weight (PLW), calibration and standardization of instruments, textural properties of harvested produce, TSS, Specific gravity, pH and acidity.

Block 2: Qualitative and Quantitative Analysis

Unit I: Destructive and Non-destructive Analysis Methods: Refractometry, spectrophotometry, non-destructive determination of colour, ascorbic acid, sugars, and starch in food crops.

Unit II: Chromatographic and Microscopic Analysis: Basic chromatographic techniques, GC, HPLC, GCMS, Electrophoresis techniques, ultra filtration. Application of nuclear techniques in harvested produce. Advanced microscopic techniques, ion leakage as an index of membrane permeability, determination of biochemical components in horticultural produce.

Unit III: Sensory Analysis: Importance of ethylene, quantitative estimation of rate of ethylene evolution, using gas chromatograph (GC). Sensory analysis techniques, control of test rooms, products and panel.

VII. Practical

- Determination of moisture, relative water content and physiological loss in weight (2)
- Determination of biochemical components in horticultural produce (3);
- Calibration and standardization of instruments (1);
- Textural properties of harvested produce (1);
- Determination of starch index (SI) (1);
- Specific gravity for determination of maturity assessment, and pH of produce (1)
- Detection of adulterations in fresh as well as processed products (2)
- Non-destructive determination of colour, ascorbic acid, vitamins, carotenoids, sugars and starch (2)
- Estimation of rate of ethylene evolution using gas chromatograph (GC) (2)
- Use of advanced microscopes (fluorescent, scanning electron microscope, phase contrast, etc.) (2)
- Class room Lectures
- Laboratory Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The students would be expected to develop skills and expertise on:

- Upkeep of laboratories and handling of research instruments
- Principles and methods of various analysis

X. Suggested Reading

- AOAC International. 2003. *Official Methods of Analysis of AOAC International*. 17th Ed.
- Gaithersburg, MD, USA, Association of Analytical Communities, USA.
- Clifton M and Pomeranz Y. 1988. *Food Analysis-Laboratory Experiments*. AVI Publication, USA.
- Leo ML. 2004. *Handbook of Food Analysis*. 2nd Ed. Vols. I-III, USA.
- Linskens HF and Jackson JF. 1995. *Fruit Analysis.* Springer.
- Pomrenz Y and Meloan CE. 1996. *Food Analysis – Theory and Practice*. CBS, USA.
- Ranganna S. 2001. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products*. 2nd Ed. Tata-McGraw-Hill, New Delhi.
- Thompson AK. 1995. *Post Harvest Technology of Fruits and Vegetables*. Blackwell Sciences. USA.

I. Course Title : Arid and Dryland Fruit Production

II. Course Code : FSC 605

III. Credit Hours : (2+0)

IV. Why this course ?

Arid and dryland regions are known for growing an array of delicious and nutritious fruits (e.g. date palm, aonla, ber etc). Over the years, notable progress has been made in respect of domestication and technological advancements. Thus a course has been developed.

V. Aim of the course

To keep abreast with latest developments and trends in production technology of arid and dryland fruit crops.

The course is organised as under:-

No.	Blocks	Units
1	Introduction	General Concepts and Current Scenario
2	Advanced Technologies	Propagation, Planting Systems and Crop Regulation
3	Management Practices	Stress Mitigation and Integrated Approaches

VI. **Theory**

Block 1: Introduction

Unit I: General Concepts and Current Scenario: Characteristics features and major constraints of the arid and dryland region, distinguishing features of the fruit species trees for adaptation in adapting to the region, nutritional and pharmaceutical importance, national problems.

Block 2: Advanced Technologies

Unit I: Propagation, Planting Systems and Crop Regulation: Recent advances in propagation – root stocks, planting systems, High density planting, crop modelling, Precision farming, decision support systems – aspects of crop regulation- physical and chemical regulation, effects on physiology and development, influence of stress factors.

Block 3: Management Practices

Unit I: Stress Mitigation and Integrated Approaches: Strategies to overcome stress effects, integrated and modern approaches in water and nutrient management, total quality management (TQM) – Current topics.

Crops

Aonla, annonas, ber, bael, jamun, date palm, cactus pear, khejri, kair, pilu,lasoda, manila, tamarind, monkey jack, mahua, khirni, amra, seabuckthorn, chilgoza, rhododendron, box myrtle, chironji, phalsa, karonda,woodapple, and other minor fruits of regional importance

VII. **Teaching Methods/ Activities**

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. **Learning outcome**

Consequent upon successful completion of the course, the students are expected to learnt about

- Fruit crops adopting to arid and drylands and their features
- Specific cultivation and management practices

IX. **Suggested Reading**

- Hiwale S. 2015. *Sustainable Horticulture in Semiarid Drylands.* Springer.
- Krishna H and Sharma RR. 2017. *Fruit Production – Minor Fruits.*Daya Publishing House, Delhi.
- More T A, Singh RS, Bhargava R and Sharma BD. 2012. *Arid Horticulture for Nutrition and Livelihood.* Agrotech Publishing Academy, Udaipur (Rajasthan).
- Pareek OP, Sharma S and Arora RK. 2007. *Underutilised Edible Fruits and Nuts*, IPGRI, Rome.
- Peter K.V. 2010. *Underutilized and Underexploited Horticultural Crops*. NIPA, New Delhi.
- Saroj PL, Dhandar DG and Vashishta BB. 2004. *Advances in Arid Horticulture*, Vol.-1 *Present Status*. IBDC, Lucknow.
- Saroj P L and Awasthi OP. 2005. *Advances in Arid Horticulture*, Vol: II: *Production Technology of Arid and Semiarid Fruits*. IBDC, Lucknow.
- Sontakke MB. 2014. *Production and Management of Fruit crops in Arid/ Drylands.* Agrotech Publishing Academy, Udaipur (Rajasthan).

I. **Course Title : Abiotic Stress Management in Fruit Crops**

II. **Course Code : FSC 606**

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

IV. **Why this course ?**

Low soil fertility coupled with unpredictable and unfavourable environments often result in stress conditions. Non-availability of optimum level of inputs and congenial weather necessitates the development of suitable managementpractices to overcome various abiotic stresses. Hence a course is customized.

V. **Aim of the course**

To updates knowledge on recent trends in management of abiotic stresses in fruit crops.

The course is organised as follows:

No.	Blocks	Units
1	Introduction	Basic Aspects and Principles
2	Stress Impact	Assessment, Physiology and Performance
3	Stress Management	Mitigation Measures and Conservation Practices

VI. Theory

Block 1: Introduction

Unit I: Basic Aspects and Principles: Stress – definition, classification, stresses due to water (high and low), temperature (high and low), radiation, wind, soil conditions (salinity, alkalinity, ion toxicity, fertilizer toxicity, etc.). Pollution – increased level of CO_2, industrial wastes, impact of stress in fruit crop production, stress indices, physiological and biochemical factors associated with stress, fruit crops suitable for different stress situations.

Block 2: Stress Impact

Unit I: Assessment, Physiology and Performance: Crop modeling for stress situations, cropping systems, assessing the stress through remote sensing, understanding adaptive features of crops for survival under stress, interaction among different stresses and their impact on crop growth and productivity.

Block 3: Stress Management

Unit I: Mitigation Measures and Conservation Practices: Greenhouse effect and methane emission and its relevance to abiotic stresses, use of anti transpirants and PGRs in stress management, mode of action and practical use, HSP inducers in stress management techniques of soil moisture conservation, mulching, hydrophilic polymers. Rain water harvesting, increasing water use efficiency, skimming technology, contingency planning to mitigate different stress situations, stability and sustainability indices.

VII. Practical

- Seed treatment/ hardening practices (2);
- Container seedling production (2);
- Analysis of soil moisture estimates (FC, ASM, PWP) (1);
- Analysis of plant stress factors, RWC, chlorophyll flourosence, chlorophyll stability index, ABA content, plant waxes, stomatal diffusive resistance, transpiration, photosynthetic rate, etc. under varied stress situations (5);

- Biological efficiencies, WUE, solar energy conversion and efficiency (2);
- Crop growth sustainability indices and economics of stress management (2);
- Visit to orchards and watershed locations (2);

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

XI. Learning outcome

On successful completion of the course, the students are expected to generate know-how on

- Various types of abiotic stresses and their effects
- Physiological processes underlying abiotic stresses
- Management and conservation practices to overcome stress

X. Suggested Reading

- Blumm A. 1988. *Plant Breeding for Stress Environments*. CRC Publication, USA.
- Christiansen, MN and Lewis CF. 1982. *Breeding Plants for Less Favourable Environments.* Wiley International Science, USA.
- Kanayama Y and Kochetor. 2015. *Abiotic Stress Biology in Horticultural Plants.* Springer.
- Kramer PJ. 1980. *Drought Stress and the Origin of Adaptation*. In: *Adaptation of Plants to*
- *Water and High Temperature Stress*. John Wiley & Sons, USA.
- Maloo SR. 2003. *Abiotic Stress and Crop Productivity*. Agrotech Publ. Academy, India.
- Nickell LG. 1983. *Plant Growth Regulating Chemicals*. CRC Publication, USA.
- Rao NKS, Shivashankar KS and Laxman RH. 2016. *Abiotic Stress Physiology of Horticultural Crops.* Springer.
- Turner NC and Kramer PJ. 1980. *Adaptation of Plants to Water and High Temperature Stress*. John Wiley & Sons, USA.

I. **Course Title : Biodiversity and Conservation of Fruit Crops**

II. **Course Code : FSC 607**

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

IV. **Why this course ?**

The availability of pertinent gene pool is of utmost importance to mitigateadverse climate and to counter diseases and pests. In addition, specific gene sources (germplasm) would always be a necessity to develop superior genotypes. Considering the importance of conserving biodiversity in fruit crops for future use, the course has been designed.

V. **Aim of the course**

To understand the status and magnitude of biodiversity and strategies in germplasm conservation of fruit crops.

The course is organised as follows:-

No.	Blocks	Units
1	General Aspects	Issues, Goals and Current Status
2	Germplasm Conservation	Collection, Maintenance and Characterization
3	Regulatory Horticulture Property Rights	Germplasm Exchange, Quarantine and Intellectual

VI. **Theory**

Block 1: General Aspects

Unit I: Issues, Goals and Current Status: Biodiversity and conservation; issues and goals- needs and challenges; present status of gene centres; world's major centres of fruit crop domestication; current status of germplasm availability/ database of fruit crops in India.

Block 2: Germplasm Conservation

Unit I: Collection, Maintenance and Characterization: Exploration and collection of germplasm; sampling frequencies; size and forms of fruitand nut germplasm collections; active and base collections.Germplasm conservation- *in situ* and *ex situ* strategies, on farm conservation; problem of recalcitrancy- cold storage of scions, tissue culture, cryopreservation, pollen and seed storage.

Block 3: Regulatory Horticulture

Unit I: Germplasm Exchange, Quarantine and Intellectual Property Rights:

Regulatory horticulture, inventory and exchange of fruit and nut germplasm, plant quarantine, phyto-sanitary certification, detection of genetic constitution of germplasm and maintenance of core collection. IPRs, Breeder's rights, Farmer's rights, PPV and FR Act.

GIS and documentation of local biodiversity, Geographicalindications, GIS application in horticultural mapping and spatial analyses of field data; benefits of GI protection; GI tagged fruit varieties in India.

VII. Practical

- Documentation of germplasm- maintenance of passport data and other records of accessions (2);
- Field exploration trips and sampling procedures (2);
- Exercise on *ex situ* conservation – cold storage, pollen/ seed storage (2);
- Cryopreservation (2);
- Visits to National Gene Bank and other centers of PGR activities (2);
- Detection of genetic constitution of germplasm (2);
- Germplasm characterization using a standardised DUS test protocol (2);
- Special tests with biochemical and molecular markers (2).

VIII. Teaching Methods/ Activities

- Class room Lectures
- Laboratory/ Field Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. Learning outcome

The student would be expected to learn about the significance of germplasm and various strategies to conserve it in the present context.

X. Suggested Reading

- Dhillon BS, Tyagi RK, Lal A and Saxena S. 2004. *Plant Genetic Resource Management. – Horticultural Crops.*Narosa Publishing House, New Delhi.
- Engles JM, Ramanath RV, Brown AHD and Jackson MT. 2002. *Managing Plant Genetic Resources,* CABI, Wallingford, UK.

- Frankel OH and Hawkes JG. 1975. *Crop Genetic Resources for Today and*

Tomorrow. Cambridge University Press, USA.

- Hancock J. 2012. *Plant Evolution and the Origin of Crops Species*. CAB International.
- Jackson M, Ford-Lloyd B and Parry M. 2014. *Plant Genetic Resources and Climate Change*. CABI, Wallingford, UK.
- Moore JN and Ballington Jr, JR. 1991. *Genetic Resources of Temperate Fruit and Nut Crops.*ISHS, Belgium.
- Peter KV. 2008. *Biodiversity of Horticultural Crops*. Vol. II. Daya Publ. House, Delhi.
- Peter KV. 2011. *Biodiversity in HorticulturalCrops*.Vol.III. Daya Publ. House, Delhi.
- Rana JC and Verma VD. 2011. *Genetic Resources of Temperate Minor Fruits (Indigenous and Exotic).* NBPGR, New Delhi.
- Rajasekharan PE, Rao V and Ramanatha V. 2019. *Conservation and Utilization of Horticultural Genetic Resources*. Springer.
- Sthapit B, *et al*. 2016. *Tropical Fruit Tree Diversity (Good Practices for in situ and ex situ conservation*). Bioversity International. Routledge, Taylor and Francis Group.
- Virchow D. 2012. *Conservation of Genetic Resources*, Springer Verlag, Berlin.

I. Course Title : Smart Fruit Production

II. Course Code : FSC 608

III. Credit Hours : (2+0)

IV. Why this course ?

In the era of automation and mechanization, several recent innovations have direct applications in fruit growing. Thus a need is felt to have course on smart innovations.

V. Aim of the course

To acquire knowledge on hi-tech innovations useful in fruit crops.

The course is structure is as under:

No.	Blocks	Units
1	Introduction	Importance and Overview
2	Crop Modelling and Forecasting	GIS, Sensors and Wireless System
3	Nanotechnology	Concepts and Methods
4	Innovative Approaches	Mechanization, Automation and Robotics

VI. **Theory**

Block 1: Introduction

Unit I: Importance and Overview: Introduction and importance; concepts and applications of artificial intelligence systems; case studies in horticulture

Block 2: Crop Modelling and Forecasting

Unit I: GIS, Sensors and Wireless Systems: Application of sensors in fruit production, crop monitoring – crop load and stress incidence forecast modules, remote sensing, Geographical Information System (GIS), Differential Geo-Positioning System (DGPS) hi-tech nursery production of fruit crops under protected conditions, ultra modern wireless based drip irrigation network.

Block 3: Nanotechnology

Unit I: Concepts and Methods: Nanotechnology for smart nutrient delivery in fruit farming, concepts and methods, practical utility, nano-fertilizers, nano-herbicides; nano-pesticides

Block 4: Innovative Approaches

Unit I: Mechanization, Automation and Robotics: Production systems amenable to automation and mechanization; automated protected structures (turn-key systems); hydroponics, aeroponics, bioreactorsfor large scale plant multiplication; Use of drones and robotics in fruit growing – robotic planters, sprayers, shakers, harvesters, stackers, etc. Visit to Hi-tech facilities.

VII. **Teaching Methods/ Activities**

- Class room Lectures
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

VIII. **Learning outcome**

After successful completion of the course, the students are expected to learn about latest innovations in automation, nanotechnology and robotics for realisingsmart fruit production.

IX. **Suggested Reading**

- Chadha *et al.* 2017. *Doubling Farmers Incomes through Horticulture*. Daya Publishing House, New Delhi.
- Chadha *et al.* 2019.*Shaping the Future of Horticulture*. Kruger Brentt Publishers, UK.
- Hewett EW. 2013. *Automation, Mechanization and Robotics in Horticulture*. *In:* Workshop on
- Emerging Postharvest Technologies. UC, Davis, USA. Peter KV. 2016. *Innovations in Horticulture*. NIPA, New Delhi.
- Prasad S, Singh D and Bhardwaj RL. 2012. *Hi-Tech Horticulture.*Agrobios (India).
- Tyagi, S. 2019. *Hi- Tech Horticulture*. Vols. 1 to 7. NIPA, New Delhi.
- Zhang Q. 2017. *Automation in Tree Fruit production – Principles and Practice*. CABI. http://horticulture.ucdavis.edu- Innovative Technology for Horticultural Department.

Selected Journals

Sr. No.	Name of the Journal	ISSN No.
1.	*Advances in Horticultural Science*	0394-6169
2.	*Acta Horticulturae*	0567-7572
3.	*American Journal of Enology and Viticulture*	0002-9254
4.	*Annals of Arid Zone*	0570-1791
5.	*Annals of Horticulture*	0974-8784
6.	*Biodiversity and Conservation*	0960-3115
7.	*Current Horticulture*	2347-7377
8.	*European Journal of Horticultural Science (Gartenbauwissenschaft)*	1611-4426
9.	*Fruits*	0248-1294
10.	*Genetic Resources and Crop Evolution*	0925-9864
11.	*Horticultural Plant Journal*	2488-0141
12.	*Horticulture Environment and Biotechnology*	2211-3452
13.	*HortScience*	0018-5345
14.	*Indian Horticulture Journal*	2249-6823

15. *Indian Journal of Arid Horticulture* Naas-1234

16. *Indian Journal of Dryland Agricultural Research and Development*0971-2062

Sr. No.	Name of the Journal	ISSN No.
17.	*Indian Journal of Horticulture*	0972-8538
18.	*International Journal of Fruit Science*	1553-8621
19.	*International Journal of Horticulture*	1927-5803
20.	*International Journal of Innovative Horticulture*	2320-0286
21.	*Journal of Applied Horticulture*	0972-1045
22.	*Journal of Horticultural Research*	2300-5009
23.	*Journal of Horticultural Science and Biotechnology (Journal of Horticultural Science, England)*	1462-0316
24.	*Journal of Horticultural Sciences*	0973-354X
25.	*Journal of Horticulture*	2376-0354
26.	*Journal of The American Society for Horticultural Science*	0003-1062
27.	*Journal of Tree Fruit Production*	1055-1387
28.	*New Zealand Journal of Crop and Horticultural Science*	0114-0671
29.	*Progressive Horticulture*	0970-3020
30.	*Scientia Horticulturae*	0304-4238
31.	*The Asian Journal of Horticulture*	0973-4767
32.	*The Journal of American Pomological Society*	1527-3741

VEGETABLE SCIENCE

Course Title with Credit Load for M.Sc. in Vegetable Science

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
VSC 501*	Production of Cool Season Vegetable Crops	2+1
VSC 502*	Production of Warm Season Vegetable Crops	2+1
VSC 503*	Growth and Development of Vegetable Crops	2+1
VSC 504*	Principles of Vegetable Breeding	2+1
VSC 505	Breeding of Self Pollinated Vegetable Crops	2+1
VSC 506	Breeding of Cross Pollinated Vegetable Crops	2+1
VSC 507	Protected Cultivation of Vegetable Crops	2+1
VSC 508	Seed Production of Vegetable Crops	2+1
VSC 509	Production of Underutilized Vegetable Crops	2+1
VSC 510	Systematics of Vegetable Crops	1+1
VSC 511	Organic Vegetable Production	1+1
VSC 512	Production of Spice Crops	2+1
VSC 513	Processing of Vegetable Crops	1+1
VSC 514	Postharvest Management of Vegetable Crops	2+1
VSC 591	Master’s Seminar	0+1
VSC 599	Master’s Research	0+30
	Total Credits	**70**

*Compulsory among major courses

I. **Course Title** : **Production of Cool Season Vegetable Crops**

II. **Course Code** : **VSC 501**

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

IV. **Why this course ?**

Cool season vegetables are a major source of dietary fibres, minerals and vitamins. Some of these vegetables also contribute protein, fat and carbohydrate. Most of the leafy and root vegetables are rich in minerals, especially in micro-elements such as copper, manganese and zinc. Vegetables differ in their temperature requirement for proper growth and development. Most of the winter vegetable crops are cultivatedin cool season when the monthly mean temperature does not exceed 21°C. Even in temperate climate, these vegetables are cultivated in spring summer in hilly tracks where the daytime temperature in summer is less than 21°C. The students of vegetable science need to have an understanding of production technology of important cool season vegetable crops and their management.

V. **Aim of the course**

To impart knowledge and skills on advancement in production technology of cool season vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Production of cool season vegetable	I Bulb and tuber crops II Cole crops II Root crops III Peas and beans IV Leafy vegetables

VI. **Theory**

Introduction, commercial and nutritional importance, origin and distribution, botany and taxonomy, area, production, productivity and constraints, soil requirements, climatic factors for yield and quality, commercial varieties/ hybrids, seed rate and seed treatment, raising of nursery, sowing/ planting time and methods, hrydroponics and aeroponics, precision farming, cropping system, nutritional including micronutrients and irrigation requirements, intercultural operations, special horticultural practices, weed control, mulching, role of plant growth regulators, physiological disorders, maturity indices, harvesting, yield, post-harvest management (grading, packaging and marketing), pest and disease management and productioneconomics of crops.

Unit I

Bulb and tuber crops—Onion, garlic and potato.

Unit II

Cole crops—Cabbage, cauliflower, kohlrabi, broccoli, Brussels sprouts and kale.

Unit III

Root crops—Carrot, radish, turnip and beetroot.

Unit IV

Peas and beans—Garden peas, french bean and broad bean.

Unit V

Leafy vegetables—Beet leaf, spinach, fenugreek, coriander and lettuce.

VII. Practical

- Scientific raising of nursery and seed treatment;
- Sowing and transplanting;
- Description of commercial varieties and hybrids;
- Demonstration on methods of irrigation, fertilizers and micronutrients application;
- Mulching practices, weed management;
- Use of plant growth substances in cool season vegetable crops;
- Study of nutritional and physiological disorders;
- Studies on hydroponics, aeroponics and other soilless culture;
- Identification of important pest and diseases and their control;
- Preparation of cropping scheme for commercial farms;
- Visit to commercial farm, greenhouse/ polyhouses;
- Visit to vegetable market;
- Analysis of benefit to cost ratio.

VIII. Teaching Methods/ Activities

- Classroom lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

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

- Appreciate the scope and scenario of cool season vegetable crops in India
- Acquire knowledge about the production technology and post-harvest

handling ofcool season vegetable crops

- Calculate the economics of vegetable production in India

X. Suggested Reading

- Bose TK, Kabir J, Maity TK, Parthasarathy VA and Som MG. 2003. *Vegetable crops*. Vols. I-III. Naya udyog.
- Bose TK, Som MG and Kabir J. (Eds.). 1993. *Vegetable crops*. Naya prokash.
- Chadha KL and Kalloo G. (Eds.). 1993-94. *Advances in horticulture* Vols. V-X. Malhotra publ. house.
- Chadha KL. (Ed.). 2002. *Hand book of horticulture*. ICAR.
- Chauhan DVS. (Ed.). 1986. *Vegetable production in India*. Ram prasad and sons.
- Fageria MS, Choudhary BR and Dhaka RS. 2000. *Vegetable crops: production technology*. Vol. II. Kalyani publishers.
- Gopalakrishanan TR. 2007. *Vegetable crops*. New India publ. agency.
- Hazra P and Banerjee MK and Chattopadhyay A. 2012. *Varieties of vegetable crops in India*, (Second edition), Kalyani publishers, Ludhiana, 199 p.
- Hazra P. 2016. *Vegetable Science*. 2nd edn, Kalyani publishers, Ludhiana.
- Hazra P. 2019. *Vegetable production and technology*. New India publishing agency, New Delhi.
- Hazra P, Chattopadhyay A, Karmakar K and Dutta S. 2011. *Modern technology for vegetable production*, New India publishing agency,New Delhi, 413p
- Rana MK. 2008. *Olericulture in India*. Kalyani publishers, New Delhi.
- Rana MK. 2008. *Scientific cultivation of vegetables*. Kalyani publishers, New Delhi. Rana MK. 2014. *Technology for vegetable production*. Kalyani publishers, New Delhi.
- Rubatzky VE and Yamaguchi M. (Eds.). 1997. *World vegetables:principles, production and nutritive values*. Chapman and Hall.
- Saini GS. 2001. *A text book of oleri and flori culture*. Aman publishing house.
- Salunkhe DK and Kadam SS. (Ed.). 1998. Hand book of vegetable science and technology: production, composition, storage and processing. Marcel dekker.
- Shanmugavelu KG. 1989. *Production technology of vegetable crops*. Oxford and IBH.
- Singh DK. 2007. *Modern vegetable varieties and production technology*.

International bookdistributing Co.

- Singh SP. (Ed.). 1989. *Production technology of vegetable crops*. Agril. comm. res. centre. Thamburaj S and Singh N. (Eds.), 2004. *Vegetables, tuber crops and spices*. ICAR. Thompson HC and Kelly WC. (Eds.). 1978. *Vegetable crops*. Tata McGraw-Hill.

I. Course Title : Production of Warm Season Vegetable Crops

II. Course Code : VSC 502

III. Credit Hours : (2+1)

IV. Why this course ?

Unlike cool-season vegetables, warm-season vegetable crops require higher soiland air temperature, thus, they are always planted after the last frost date ranging from late spring after the last frost date to late summer.Daytime temperature may still be warm enough but drop so much at night- time that the weather is not suitable for warm-season crops any longer. In general summer vegetables require a little higher temperature than winter vegetables for optimum growth. In summer vegetables, the edible portion is mostly botanical fruit. The students of vegetable science need to have an understanding of production technology of important warm season vegetable crops and thereafter their management.

V. Aim of the course

To impart knowledge and skills on advancement in production technology of warm season vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Production of warm season vegetable	1. Fruit vegetable crops 2. Beans 3. Cucurbits 4. Tuber crops 5. Leafy vegetables

VI. Theory

Introduction, commercial and nutritional importance, origin and distribution, botany and taxonomy, area, production, productivity and constraints, soil requirements, climatic factors for yield and quality, commercial varieties/ hybrids, seed rate and seed treatment, raising of nursery including grafting technique, sowing/ planting time and methods, precision farming, cropping system, nutritional including micronutrients and irrigation requirements, intercultural operations, special horticultural practices namely hydroponics, aeroponics, weed control, mulching, role of plant growth regulators, physiological disorders, maturity indices, harvesting, yield, post-harvest management (grading, packaging and marking), pest and disease management and economics of crops.

Unit I

Fruit vegetables—Tomato, brinjal, hot pepper, sweet pepper and okra.

Unit II

Beans—Indian bean (Sem), cluster bean and cowpea.

Unit III

Cucurbits—Cucumber, melons, gourds, pumpkin and squashes.

Unit IV

Tuber crops—Sweet potato, elephant foot yam, tapioca, taro and yam.

Unit V

Leafy vegetables—Amaranth and drumstick.

VII. **Practical**

- Scientific raising of nursery and seed treatment;
- Sowing, transplanting, vegetable grafting;
- Description of commercial varieties and hybrids;
- Demonstration on methods of irrigation, fertilizers and micronutrients application;
- Mulching practices, weed management;
- Use of plant growth substances in warm season vegetable crops;
- Study of nutritional and physiological disorders;
- Studies on hydroponics, aeroponics and other soilless culture;
- Identification of important pest and diseases and their control;
- Preparation of cropping scheme for commercial farms;
- Visit to commercial farm, greenhouse/ polyhouses;
- Visit to vegetable market;
- Analysis of benefit to cost ratio.

VIII. **Teaching Methods/ Activities**

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

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

- Appreciate the scope and scenario of warm season vegetable crops in India
- Acquire knowledge about the production technology and post-harvest handling ofwarm season vegetable crops
- Calculate the economics of vegetable production in India

Suggested Reading

- Bose TK, Kabir J, Maity TK, Parthasarathy VA and Som MG. 2003. *Vegetable crops*. Vols. I-III. Naya udyog.
- Bose TK, Som MG and Kabir J. (Eds.). 1993. *Vegetable crops*. Naya prokash.
- Chadha KL and Kalloo G. (Eds.). 1993-94. *Advances in horticulture* Vols. V-X. Malhotra publ. house.
- Chadha KL. (Ed.). 2002. *Hand book of horticulture*. ICAR.
- Chauhan DVS. (Ed.). 1986. *Vegetable production in India*. Ram prasad and sons.
- Fageria MS, Choudhary BR and Dhaka RS. 2000. *Vegetable crops: production technology*. Vol. II. Kalyani.
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- Hazra P. 2019. *Vegetable production and technology*. New India publishing agency, New Delhi.
- Hazra P, Chattopadhyay A, Karmakar K and Dutta S. 2011. *Modern technology for vegetable production*, New India publishing agency, New Delhi, 413p
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- Rana MK. 2008. *Scientific cultivation of vegetables*. Kalyani Publishers, New Delhi.
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- Saini GS. 2001. *A text book of oleri and flori culture*. Aman publishing house.
- Salunkhe DK and Kadam SS. (Ed.). 1998. *Hand book of vegetable science and technology: production, composition, storage and processing*. Marcel dekker.
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- Singh SP. (Ed.). 1989. *Production technology of vegetable crops*. Agril. comm. res. centre. Thamburaj S and Singh N. (Eds.). 2004. *Vegetables, tuber crops and spices*. ICAR. Thompson HC and Kelly WC. (Eds.). 1978. *Vegetable crops*. Tata McGraw-Hill.

I. Course Title : Growth and Development of Vegetable Crops

II. Course Code : VSC 503

III. Credit Hours : (2+1)

IV. Why this course ?

In agriculture, the term plant growth and development is often substituted with cropgrowth and yield since agriculture is mainly concerned with crops and their economic products. Growth, which is irreversible quantitative increase in size, mass, and/ or volume of a plant or its parts, occurs with an expenditure of metabolic energy. Plant development is an overall term,which refers to various changes that occur during its life cycle. In vegetable crops, development is a series of processes from the initiation of growth to death of a plant or its parts. Growth and development are sometimes used interchangeably in conversation, but in a botanical sense, they describe separate events in the organization of the mature plant body. The students of vegetable science need to have an understanding of growth and development of vegetable crops.

V. Aim of the course

To teach the physiology of growth and development of vegetable crops The course is constructed given as under:

No.	Block	Unit
1.	Growth and development of vegetable crops	1. Introduction and phytohormones 2. Physiology of dormancy and germination 3. Abiotic factors 4. Fruit physiology 5. Morphogenesis and tissue culture

VI. Theory

Unit I

Introduction and phytohormones—Definition of growth and development; Cellular structures and their functions; Physiology of phyto-hormones functioning/ biosynthesis and mode of action; Growth analysis and its importance in vegetable production.

Unit II

Physiology of dormancy and germination—Physiology of dormancy and germination of vegetable seeds, tubers and bulbs; Role of auxins, gibberellilns, cyktokinins andabscissic acid; Application of synthetic PGRs including plant growth retardants and inhibitors for various purposes in vegetable crops; Role and mode of action of morphactins, antitranspirants, anti-auxin, ripening retardant and plant stimulants in vegetable crop production.

Unit III

Abiotic factors—Impact of light, temperature, photoperiod, carbon dioxide, oxygen and other gases on growth, development of underground parts, flowering and sex expression in vegetable crops; Apical dominance.

Unit IV

Fruit physiology—Physiology of fruit set, fruit development, fruit growth, flower and fruit drop; parthenocarpy in vegetable crops; phototropism, ethylene inhibitors, senescence and abscission; fruit ripening and physiological changes associated with ripening.

Unit V

Morphogenesis and tissue culture—Morphogenesis and tissue culture techniques in vegetable crops; Grafting techniques in different vegetable crops.

VII. Practical

- Preparation of plant growth regulator’s solutions and their application;
- Experiments in breaking and induction of dormancy by chemicals;
- Induction of parthenocarpy and fruit ripening;
- Application of plant growth substances for improving flower initiation, changing sex expression in cucurbits and checking flower and fruitdrops and improving fruit set in solanaceous vegetables;
- Growth analysis techniques in vegetable crops;
- Grafting techniques in tomato, brinjal, cucumber and sweet pepper.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation

- Hands on training of different procedure
- Group discussion

IX. Learning outcome

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

- Acquire knowledge about the growth and development of plants in vegetable crops
- Distinguish between primary and secondary growth in plant stems
- Understand how hormones affect the growth and development of vegetable crops

X. Suggested Reading

- Bleasdale JKA. 1984. *Plant physiology in relation to horticulture* (2nd Edition) MacMillan. Gupta US. Eds. 1978. *Crop physiology*. Oxford and IBH, New Delhi.
- Kalloo G. 2017. *Vegetable grafting: Principles and practices*. CAB International Krishnamoorti HN. 1981. *Application growth substances and their uses in agriculture*. Tata McGraw Hill, New Delhi.
- Leopold AC and Kriedemann PE. 1981. *Plant growth and development*, Tata McGraw-Hill,New Delhi.
- Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*.Studium Press LLC, P.O. Box722200, Houston, Texas 77072, USA, 678p.
- Peter KV. (Eds). 2008. *Basics of horticulture*. New India publication agency, New Delhi. Rana MK. 2011. *Physio-biochemistry and Biotechnology of Vegetables*. New India Publishing Agency, Pritam Pura, New Delhi.
- Saini *et al.* (Eds.). 2001. *Laboratory manual of analytical techniques in horticulture*. Agrobios, Jodhpur.
- Wien HC. (Eds.). 1997. *The physiology of vegetable crops*. CAB International.

I. Course Title : Principles of Vegetable Breeding
II. Course Code : VSC 504
III. Credit Hours : (2+1)

IV. Why this course ?

Plant breeding has been practiced for thousands of years, since beginning of human civilization. Vegetable breeding, which is an art and science of changing the traits of plants in order to produce desired traits, has been used to improve the quality of nutrition in products for human beings. A breeding programme, which is needed if current varieties are not producing up to the capacity of the environment, can be accomplished through many different techniques ranging from simply selecting plants with desirable characteristics, make use of knowledge of genetics and chromosomesto more complex molecular techniques. When different genotypes exhibit differential responses to different sets of environmental conditions, a genotype x environment (GxE) interaction is said to occur. Breeding high yielding open pollinated varieties and hybrids, and exploitation of location specific component of genotypic performance are the only options left to reduce this increasing gap between the production and requirements in view of decreasing land resources. Noevertheless, vegetable breeding is an integralpart of plant breeding but this will be re-modeled to suit to breeding of different vegetables crops. The students of vegetable science who are having breeding as major subject need to have an understanding of vegetable breeding principles.

V. Aim of the course

To teach basic principles and practices of vegetable breeding

The course is constructed given as under:

No.	Block	Unit
1.	Principles of vegetable breeding	I. Importance and history II. Selection procedures III. Heterosis breeding IV. Mutation breeding V. Polyploid breeding VI. Ideotype breeding

VI. Theory

Unit I

Importance and history- Importance, history and evolutionary aspects of vegetable breeding and its variation from cereal crop breeding.

Unit II

Selection procedures- Techniques of selfing and crossing; Breeding systems and methods; Selection procedures and hybridization; Genetic architecture; Breedingfor biotic stress (diseases, insect pests and nematode), abiotic stress (temperature, moisture and salt) resistance and quality improvement; Breeding for water use efficiency (WUE) and nutrients use efficiency (NUE).

Unit III

Heterosis breeding- Types, mechanisms and basis of heterosis, facilitating mechanisms like male sterility, self-incompatibility and sex forms.

Unit IV

Mutation and Polyploidy breeding; Improvement of asexually propagated vegetable crops and vegetables suitable for protected environment.

Unit V

Ideotype breeding- Ideotype breeding; varietal release procedure; DUS testing in vegetable crops; Application of biotechnology in vegetable cropimprovement.

VII. Practical

- Floral biology and pollination behaviour of different vegetables;
- Techniques of selfing and crossing of different vegetables, viz., Cole crops, okra,cucurbits, tomato, eggplant, hot pepper, etc.;
- Breeding system and handling of filial generations of different vegetables;
- Exposure to biotechnological lab practices;
- Visit to breeding farms.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

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

- Acquire knowledge about the principles of vegetable breeding
- Improve yield, quality, abiotic and biotic resistance, other important traits ofvegetable crops

- Understand how the basic principles are important to start breeding of vegetablecrops

X. Suggested Reading

- Allard RW. 1960. *Principle of plant breeding*. John Willey and Sons, USA. Kalloo G. 1988. *Vegetable breeding* (Vol. I, II, III). CRC Press, Fl, USA.
- Kole CR. 2007. *Genome mapping and molecular breeding in plants-vegetables*. Springer, USA. Peter KVand Pradeep Kumar T. 1998. Genetics and breeding of vegetables. ICAR, New Delhi, p.488.
- Prohens J and Nuez F. 2007. *Handbook of plant breeding-vegetables* (Vol I and II). Springer, USA.
- Singh BD. 2007. *Plant breeding- principles and methods* (8th edn.). Kalyani Publishers, New Delhi.
- Singh Ram J. 2007. *Genetic resources, chromosome engineering, and crop improvement-vegetable crops* (Vol. 3). CRC Press, Fl, USA.

I. Course Title : Breeding of Self Pollinated Vegetable Crops

II. Course Code : VSC 505

III. Credit Hours : (2+1)

IV. Why this course ?

Self-pollination, which is considered the highest degree of inbreeding a plant can achieve, promotes homozygosity of all gene loci and traits of the sporophyte and restricts the creation of new gene combinations (no introgression of new genes through hybridization). The progeny of a single plant is homogeneous due to self pollination. A population of self-pollinated species comprises a mixture of homozygous lines. New genes may arise through mutation but such change is restricted to individual lines or the progenies of the mutant plant. Since a self-pollinated cultivar is generally one single genotype reproducing itself, breeding of self-pollinated species usually entails identifying one superior genotype (or a few) and its multiplication. Specific breeding methods commonly used for self- pollinated species are pure- line selection, pedigree breeding, bulk populations and backcross breeding. Thestudents of vegetable science who take breeding as a minor subject need to have an understanding of breeding of self pollinated vegetable crops.

V. **Aim of the course**

To impart comprehensive knowledge about principles and practices of breeding of self pollinated vegetable crops

The course is constructed given as under:

No.	Block	Unit
	Breeding of self pollinated vegetable crops	I. Potato II. Fruit vegetables III. Garden peas and cowpea IV. Beans V. Leafy vegetables

VI. **Theory**

Origin, botany, taxonomy, wild relatives, cytogenetics and genetics, types of

pollination and fertilization mechanism, sterility, breeding objectives, breeding methods (introduction, selection, hybridization, mutation and polyploidy), varieties and varietal characterization, resistance breeding for biotic and abiotic stresses, breeding for protected environment and quality improvement, molecular markers and marker's assisted breeding; QTLs, PPV and FR Act.

Unit I

Tuber crops: Potato.

Unit II

Fruit vegetables- Tomato, eggplant, hot pepper, sweet pepper and okra.

Unit III

Leguminous vegetables- Garden peas and cowpea.

Unit IV

Leguminous vegetables: French bean, Indian bean, cluster bean and broad bean.

Unit V

Leafy vegetables- Lettuce and fenugreek.

VII. **Practical**

- Floral mechanisms favouring self and often cross pollination;

- Progeny testing and development of inbred lines;
- Selection of desirable plants from breeding population, observations and analysis of various qualitative and quantitative traits in germplasm, hybrids and segregating generations;
- Palynological studies, selfing and crossing techniques;
- Hybrid seed production of vegetable crops in bulk;
- Screening techniques for biotic and abiotic stress resistance in above mentionedcrops;
- Molecular marker techniques to identify useful traits in the vegetable crops andspecial breeding techniques;
- Visit to breeding farms;

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

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

- Acquire knowledge about the breeding of self pollinated vegetable crops
- Improve yield, quality, abiotic and biotic resistance and other important traits ofvegetable crops
- Understand how to start the breeding of self pollinated vegetable crops

X. Suggested Reading

- Allard RW. 1999. *Principles of plant breeding*. John Wiley and Sons.
- Basset MJ. (Ed.). 1986. *Breeding vegetable crops*. AVI Publ.
- Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005, Plant genetic resources: horticultural crops. Narosa Publ. House.
- Fageria MS, Arya PS and Choudhary AK. 2000, *Vegetable crops: Breeding and seed production* Vol. I. Kalyani.
- Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.
- Hayes HK, Immer FR and Smith DC. 1955. *Methods of plant breeding*. McGraw-Hill.

- Hayward MD, Bosemark NO and Romagosa I. (Eds.). 1993. *Plant Breeding-principles and prospects*. Chapman and Hall.
- Hazra P and Som MG. 2015. Vegetable science (Second revised edition), Kalyani publishers, Ludhiana, 598 p.
- Hazra P and Som MG. 2016. *Vegetable seed production and hybrid technology* (Second revised edition), Kalyani Publishers, Ludhiana, 459 p
- Kalloo G. 1988. *Vegetable breeding*. Vols. I-III. CRC Press.
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- Paroda RS and Kalloo G. (Eds.). 1995. *Vegetable research with special reference to hybridtechnology in Asia-Pacific Region*. FAO.
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- Peter KV and Hazra P (Eds). 2015. *Hand book of vegetables* Volume II.Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509 p.
- Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume III.Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 634 p.
- Rai N and Rai M. 2006. *Heterosis breeding in vegetable crops*. New India Publ. Agency.
- Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi. Simmonds NW. 1978. *Principles of crop improvement*. Longman. Singh BD. 1983. Plant Breeding. Kalyani Publishers, New Delhi.
- Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. International Book Distributing Co.
- Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*.

I. Course Title : Breeding of Cross Pollinated Vegetable Crops

II. Course Code : VSC 506

III. Credit Hours : (2+1)

IV. Why this course?

The important methods of breeding in cross-pollinated vegetable species are (i) mass selection, (ii) development of hybrid varieties and (ii) development of synthetic varieties. Since cross-pollinated vegetable crops are naturally hybrid (heterozygous) for many traits and lose vigour as they become purebred (homozygous), a goal of each of these breeding methods is to preserve or restore heterozygosity in cross pollinated vegetable crops. The students of vegetable science who take breeding as a minor subject need to have an understanding of breeding of cross pollinated vegetable crops.

V. Aim of the course

To impart comprehensive knowledge about principles and practices of cross pollinated vegetable crops breeding.

The course is constructed given as under:

No.	Block	Unit
1.	Breeding of cross pollinated crops	I. Cucurbitaceous cropsvegetable II. Cole crops III. Root and bulb crops IV. Tuber crops V. Leafy vegetables

VI. Theory

Origin, botany, taxonomy, cytogenetics, genetics, types of pollination and fertilization, mechanism, sterility and incompatibility, breeding objectives, breeding methods (introduction, selection, hybridization, mutation, polyploidy), varieties and varietal characterization, resistance breeding for biotic and abiotic stresses, quality improvement, molecular markers and marker assisted breeding, and QTLs, PPVand FR act

Unit I

Cucurbitaceous crops—Gourds, melons, cucumber, pumpkin and squashes.

Unit II

Cole crops—Cauliflower, cabbage, kohlrabi, broccoli and brussels sprouts.

Unit III

Root and bulb crops—Carrot, radish, turnip, beet root and onion.

Unit IV

Tuber crops—Sweet potato, tapioca, taro and yam.

Unit V

Leafy vegetables—Beet leaf, spinach, amaranth and coriander.

VII. Practical

- Floral mechanisms favouring cross pollination;
- Development of inbred lines;
- Selection of desirable plants from breeding population;
- Observations and analysis of various quantitative and qualitative traits in germplasm, hybrids and segregating generations;
- Induction of flowering, palynological studies, selfing and crossing techniques;
- Hybrid seed production of vegetable crops in bulk; Screening techniques for bioticand abiotic stress resistance in above mentioned crops;
- Demonstration of sib-mating and mixed population;
- Molecular marker techniques to identify useful traits in vegetable crops and specialbreeding techniques;
- Visit to breeding blocks.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation individual or in group
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

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

- Acquire knowledge about the breeding of cross pollinated vegetable crops
- Improve yield, quality, abiotic and biotic resistance, and important traits of crosspollinated vegetable crops
- Understand how to start the breeding of cross pollinated vegetable crops

X. Suggested Reading

- Allard RW. 1999. *Principles of plant breeding*. John Wiley and Sons. Basset MJ. (Ed.). 1986. *Breeding vegetable crops*. AVI Publ.

- Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa publ. house.
- Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: breeding and seed production* Vol. I. Kalyani.
- Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.
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- Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. Agro botanical publ.
- Paroda RS and Kalloo G. (Eds.). 1995. *Vegetable research with special reference to hybridtechnology in Asia-Pacific region*. FAO.
- Peter KV and Pradeepkumar T. 2008. *Genetics and breeding of vegetables.* revised, ICAR. Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 678p.
- Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume II and III.Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509 p.
- Prohens J and Nuez F. 2007. *Handbook of Plant Breeding- Vegetables* (Vol I and II), Springer, USA.
- Rai N and Rai M. 2006. *Heterosis breeding in vegetable crops*. New India Publ. Agency.
- Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi. Simmonds NW. 1978. *Principles of crop improvement*. Longman.

- Singh BD. 1983. *Plant breeding*. Kalyani Publishers, New Delhi.
- Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. Internationalbook distributing Co.
- Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

I. Course Title : Protected Cultivation of Vegetable Crops

II. Course Code : VSC 507

III. Credit Hours : (2+1)

IV. Why this course ?

India is the second largest producer of vegetable crops in the world. However, its vegetable production is much less than the requirement, if a balanced diet is provided to every individual. There are different ways and means to achieve this target. Protected cultivation, which is the modification of the natural environment to achieve optimum plant growth. Is the most intensive form of crop production with a yield per unit area up to ten times superior to that of a field crop. During winter under north-east Indian conditions, it is difficult to grow tomato, capsicum, cucurbits, french bean, amaranth, etc. in open field. However, various types of protected structure have been developed for growing some high value crops by providing protection from the excessive cold. Production of off-season vegetable nurseries under protected structure has become a profitable business. The main purpose of raising nursery plants in protected structure is to get higher profit and disease free seedlings in off-season to raise early cropin protected and open field condition. The low cost polyhouse is economical for small and marginal farmers, who cannot afford huge cost of high-tech polyhouse. Besides supplying the local markets, the production of polyhouse vegetables is greatly valued for its export potential and plays an important role in the foreign trade balance of several national economies. The students of vegetable science need to have an understanding of protected cultivation of vegetable crops.

V. Aim of the course

To impart latest knowledge about growing of vegetable crops under protected environmental conditions

The course is constructed given as under:

No.	Block	Unit

1.	Protected cultivation of vegetable crops	I. Scope and importance II. Types of protected structure III. Abiotic factors IV. Nursery raising V. Cultivation of crops VI. Solutions to problems

VI. Theory

Unit I

Scope and importance- Concept, scope and importance of protected cultivation of vegetable crops; Principles, design, orientation of structure, low and high cost polyhouses/ greenhouse structures.

Unit II

Types of protected structure- Classification and types of protected structures- greenhouse/ polyhouses, plastic-non plastic low tunnels, plastic walk intunnels, high roof tunnels with ventilation, insect proof net houses, shed net houses, rain shelters, NVP, climate control greenhouses, hydroponics and aeroponics, aquaponics; Soil and soilless media for bed preparation; Design andinstallation of drip irrigation and fertigation system.

Unit III

Abiotic factors- Effect of environmental factors and manipulation of temperature, light, carbon dioxide, humidity, etc. on growth and yield of different vegetables.

Unit IV

Nursery raising- High tech vegetable nursery raising in protected structures using plugs and portrays, different media for growing nursery under protected cultivation; Nursery problems and management technologies including fertigation.

Unit V

Cultivation of crops- Regulation of flowering and fruiting in vegetablecrops; Technology for raising tomato, sweet pepper, cucumber and other vegetables in protected structures, including varieties and hybrids, training, pruning and staking in growing vegetables under protected structures.

Unit VI

Solutions to problems- Problems of growing vegetables in protected structures and their remedies, physiological disorders, insect and disease management in protected structures; Use of protected structures for seed production; Economics of greenhouse crop production.

VII. Practical

- Study of various types of protected structure;
- Study of different methods to control temperature, carbon dioxide and light;
- Study of different types of growing media, training and pruning systems in greenhouse crops;
- Study of fertigation and nutrient management under protected structures;
- Study of insect pests and diseases in greenhouse and its control;
- Use of protected structures in hybrid seed production of vegetables;
- Economics of protected cultivation (Any one crop);
- Visit to established green/ polyhouses/ shade net houses in the region.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

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

- Appreciate the scope and scenario of protected cultivation of vegetable crops inIndia
- Acquire knowledge about the effect of abiotic factors on growth, flowering and production of vegetable crops
- Gaining knowledge about the designing of various low cost protected structures
- Adopting the raising of vegetable seedlings in low cost protected structures asentrepreneur

X. Suggested Reading

- Chadha KL and Kalloo G. (Eds.). 1993-94. *Advances in horticulture*. Malhotra Pub. House. Chandra S and Som V. 2000. *Cultivating vegetables in green house*. Indian horticulture 45:17-18.
- Kalloo G and Singh K. (Eds.). 2000. *Emerging scenario in vegetable research anddevelopment*.Research periodicals and Book publ. house.
- Parvatha RP. 2016. *Sustainable crop protection under protected cultivation*.

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- Singh B. 2005. *Protected cultivation of vegetable crops*. Kalyani publishers, New Delhi
- Singh DK and Peter KV. 2014. *Protected cultivation of horticultural crops* (1st Edition) New India publishing agency, New Delhi.
- Singh S, Singh B and Sabir N. 2014. *Advances in protected cultivation*. New India publishing agency, New Delhi.
- Tiwari GN. 2003. *Green house technology for controlled environment*. Narosa publ. house.

I. Course Title : Seed Production of Vegetable Crops

II. Course Code : VSC 508

III. Credit Hours : (2+1)

IV. Why this course ?

Enhancing yield and quality of vegetable crops depends upon a number of factors. The inputs like fertilizers, irrigation and plant protection measures and suitable agronomic practices contribute greatly towards improving yield and quality of the vegetable produce. If good quality seed is not used, the full benefits of such inputs and agronomic practices can not be realized. The use of high quality seed thus, plays a pivotal role in the production of vegetable crops. It is, therefore, important to use the seed conforming to the prescribed standards. A good quality seed should have high genetic and physical purity, proper moisture content and good germination. It should also be free from seed borne diseases and weed seeds. The quality of the produce will deteriorate if these factors are overlooked. Out crossing, physical admixtures and mutations are the prime factors responsible for the deterioration of seed quality. A variety could be saved from deteriorationif proper checks are madeat different stages of seed multiplication. It is also extremely important to maintain high genetic purity of a variety. The students of vegetable science need to have an understanding of seed production technology of vegetable crops and their essential processingbefore supplying them to the market or further use.

V. Aim of the course

To impart a comprehensive knowledge and skills on quality seed production of vegetable crops

The course is constructed given as under:

No.	Block	Unit
1.	Seed production of vegetable crops	
		I. Introduction, history, propagation and reproduction
		II. Agro-climate and methods of seed production
		III. Seed multiplication and its qualitymaintenance
		IV. Seed harvesting, extraction and its processing
		V. Improved agro-techniques and field and seedstandards

VI. Theory

Unit I

Introduction, history, propagation and reproduction—Introduction, definitionof seed and its quality, seed morphology, development and maturation; Apomixis and fertilization; Modes of propagation and reproductive behaviour; Pollination mechanisms and sex forms in vegetables; History of vegetable seed production; Status and share of vegetable seeds in seed industry

Unit II

Agro-climate and methods of seed production—Agro-climate and its influence on quality seed production; Deterioration of crop varieties, genetical and agronomic principles of vegetable seed production; Methods of seed production, hybrid seeds and techniques of large scale hybrid seed production; Seed village concept

Unit III

Seed multiplication and its quality maintenance—Seed multiplication ratios and replacement rates in vegetables; Generation system of seed multiplication; Maintenance and production of nucleus, breeder, foundation, certified/ truthful label seeds; Seed quality and mechanisms of genetic purity testing

Unit IV

Seed harvesting, extraction and its processing—Maturity standards; Seed harvesting, curing and extraction; Seed processing, viz., cleaning, drying and treatment of seeds, seed health and quality enhancement, packaging and marketing; Principles of seed storage; Orthodox and recalcitrant seeds; Seed dormancy

Unit V

Improved agro-techniques and field and seed standards—Improved agro-techniques; Field and seed standards in important solanaceous, leguminous and cucurbitaceous vegetables, cole crops, leafy vegetables, bulbous and root crops and okra; clonal propagation and multiplication in vegetative propagated crops; Seed plot techniqueand true potato seed production in potato

VII. Practical

- Study of floral biology and pollination mechanisms in vegetables;
- Determination of modes of pollination;
- Field and seed standards;
- Use of pollination control mechanisms in hybrid seed production of importantvegetables;
- Maturity standards and seed extraction methods;
- Seed sampling and testing;
- Visit to commercial seed production areas;
- Visit to seed processing plant;
- Visit to seed testing laboratories.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

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

- Appreciate the scope and scenario of seed production of vegetable crops in India
- Acquire knowledge about the complete seed production technology, extraction andpost-extraction processing of vegetable seeds
- Adoption of seed production of vegetable crops as entrepreneur

X. Suggested Reading

- Agarwaal PK and Anuradha V. 2018. *Fundamentals of seed science and technology*. Brilliant publications, New Delhi.
- Agrawal PK and Dadlani M. (Eds.). 1992. *Techniques in seed science and technology*. Southasian Publ.

- Agrawal RL. (Ed.). 1997. *Seed technology*. Oxford and IBH.
- Basra AS. 2000. *Hybrid seed production in vegetables*. CRC press, Florida, USA.
- Bench ALR and Sanchez RA. 2004. *Handbook of seed physiology*. Food products press, NY/ London.
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- Copland LO and McDonald MB. 2004. *Seed science and technology*, Kluwer Academic Press. Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: breeding and seed production*. Vol. I. Kalyani Publishers, New Delhi.
- George RAT. 1999. *Vegetable seed production* (2nd Edition). CAB International.
- Kalloo G, Jain SK, Vari AK and Srivastava U. 2006. *Seed: A global perspective*. Associated publishing company, New Delhi.
- Hazra P and Som HG. 2015. *Seed production and hybrid technology of vegetable crops*. Kalyani publishers, Ludhiana.
- Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. Agro botanical publ.
- More TA, Kale PB and Khule BW. 1996. *Vegetable seed production technology*. Maharashtrastate seed corp.
- Rajan S and Markose BL. 2007. *Propagation of horticultural crops*. New India publ. agency. Singh NP, Singh DK, Singh YK and Kumar V. 2006. *Vegetable seed production technology*. International book distributing Co.
- Singh SP. 2001. *Seed production of commercial vegetables*. Agrotech publ. academy. Singhal NC. 2003. *Hybrid seed production*. Kalyani publishers, New Delhi

I. Course Title : Production of Underutilized Vegetable Crops

II. Course Code : VSC 509

III. Credit Hours : (2+1)

IV. Why this course ?

With increasing population and fast depletion of natural resources, it has become essential to explore the possibilities of using newer indigenous plant resources. Underutilized crops are plant species that are used traditionally by the country people for their food, fibre, fodder, oil, or medicinal properties but have yet to be adopted by large scale agriculturalists. In general, underutilized plants constitute those plant species that occur as life support species in extreme environmental conditions and threatened habitats, having genetic tolerance to survive under harsh conditions and possess qualities of nutritional and/ or industrial importance for a variety of purposes. Underutilized crops are those plant species with under-exploited potential for contributing to food security, health (nutritional or medicinal), income generation and environmental services. Once the underutilized food crops are properly utilized, they may help to contribute in food security, nutrition, health, income generation and environmental services. The underutilized crops can be defined as the crops, which being region specific are less available, less utilized or rarely used. These underutilized crop species have also been described as *rare*, *minor*, *orphan*, *promising* and little-used vegetable crops. The students of vegetable science need to have an understanding of production technology of underutilizedvegetable crops.

V. Aim of the course

To impart knowledge about production technology of lesser utilized vegetable cropsThe course is constructed given as under:

No.	Block	Unit
1.	Production of underutilized cropsvegetable crops	I. Stem and bulb
		II. Cole and salad crops
		III. Gourds and melons
		IV. Leafy vegetables
		V. Yams and beans

VI. Theory

Importance and scope, botany and taxonomy, climate and soil requirement, commercial varieties/ hybrids, improved cultural practices, physiological disorders, harvesting and yield, plant protection measures and post harvest management of:

Unit I

Stem and bulb crops—Asparagus, leek and chinese chive

Unit II

Cole and salad crops—Red cabbage, chinese cabbage, kale, sweet corn and baby corn

Unit III

Leafy vegetables—Celery, parsley, indian spinach (poi), spinach, chenopods, chekurmanis and indigenous vegetables of regional importance

Unit IV

Gourds and melons—Sweet gourd, spine gourd, teasle gourd, round gourd, and little/ Ivy gourd, pointed gourd, kachri, long melon, snap melon and gherkin

Unit V

Yams and beans—Elephant foot yam, yam, yam bean, lima bean, winged bean, jack bean and sword bean

VII. Practical

- Identification and botanical description of plants and varieties;
- Seed/ planting material;
- Production, lay out and method of planting;
- Important cultural operations;
- Identification of important pests and diseases and their control;
- Maturity standards and harvesting;
- Visit to local farms.

Teaching Methods/ Activities

- Delivering of lectures by power point presentation
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

Learning outcome

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

- Appreciate the scope and scenario of production of underutilized vegetable cropsin India
- Acquire knowledge about the production technology of underutilized

vegetablecrops

- Adopting production of lesser utilised crops as entrepreneur

Suggested Reading

- Bhat KL. 2001. *Minor vegetables-untapped potential*. Kalyani publishers, New Delhi.
- Indira P and Peter KV. 1984. *Unexploited tropical vegetables*. Kerala agricultural university, Kerala.
- Pandey AK. 2011. *Aquatic vegetables.* Agrotech publisher academy, New Delhi.
- Peter KV. (Eds.). 2007-08. *Underutilized and underexploited horticultural crops*. Vol.1-4, New India publishing agency, Lucknow.
- Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 678p.
- Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume II and III. Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509 p.
- Rana MK. 2018. *Vegetable crop science*. CRC Press Taylor and Francis Group 6000 Broken Sound Parkway NW, Suite 300 Boca Raton, FL 33487-2742 ISBN: 978-1-1380-3521-8
- Rubatzky VE and Yamaguchi M. 1997. *World vegetables: vegetable crops*. NBPGR, New Delhi.

I. Course Title : Systematics of Vegetable Crops

II. Course Code : VSC 510

III. Credit Hours : (1+1)

IV. Why this course ?

Systematics is fundamental to our understanding of the world around us as it provides basis for understanding the patterns of diversity on earth. Vegetable systematics is the science of botanical diversity of vegetable crops on earth, including variation from the level of genes within an individual to individuals, populationsand species. The primary aim of systematics is to discover all the branches of the tree of life, document evolutionary changes occurring along those branches, and describe all the species on earth (the tips of the branches). The secondary aim of systematic is to analyze and synthesize information into a classification that reflects evolutionary relationships, to organize this information into a useful, retrievable form to gain insight into evolutionary processes that lead to diversity.

V. **Aim of the course**

VI. To impart knowledge on morphological, cytological and molecular vegetable crops

VII. The course is constructed given as under:

No.	Block	Unit
1	Systematics of vegetable crops	I. Significance of systematics II Origin and evolution III. Botanical and morphological description IV. Cytology V. Molecular marker

II. **Theory**

Unit I

Significance of systematic—Significance of systematics and crop diversity in vegetable crops; Principles of classification; different methods of classification; Salient features of international code of nomenclature of vegetable crops

Unit II

Origin and evolution—Origin, history, evolution and distribution of vegetable crops

Unit III

Botanical and morphological description—Botanical description of families, genera and species covering various tropical, subtropical and temperate vegetables; Morphological keys to identify important families, floral biology, floral formula and diagram; Morphological description of all parts of vegetables

Unit IV

Cytology—Karyotype of vegetable crops

Unit V

Molecular markers—Importance of molecular markers in evolution of vegetable crops; Molecular markers as an aid in characterization and taxonomy of vegetablecrops

III. **Practical**

- Identification, description, classification and maintenance of vegetable species and varieties;
- Survey, collection of allied species and genera locally available;
- Preparation of keys to the species and varieties;
- Methods of preparation of herbarium and specimens.

IV. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

V. Learning outcome

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

- Acquire knowledge on identification, description, classification and maintenanceof vegetable species and varieties
- Collecting locally available allied species of vegetable crops
- Preparing herbarium and specimens

VI. Suggested Reading

- Chopra GL. 1968. *Angiosperms- systematics and life cycle*. S. Nagin Dutta AC. 1986. *A class book of botany*. Oxford Univ. Press.
- Pandey BP. 1999. *Taxonomy of angiosperm*. S. Chand and Co
- Peter KV and Pradeepkumar T. 2008. *Genetics and breeding of vegetables*. (Revised), ICAR. Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 678p.
- Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume II.Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509p.
- Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume III.Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 634p.
- Simmonds NW and Smartt J. 1995. *Evolution of crop plants*. Wiley-Blackwell. Soule J. 1985. *Glossary for Horticultural Crops*. John Wiley and Sons.
- Srivastava U, Mahajan RK, Gangopadyay KK, Singh M and Dhillon BS. 2001. *Minimal descriptors of agri-horticultural crops*. Part-II: Vegetable Crops. NBPGR, New Delhi.
- Vasistha. 1998. *Taxonomy of angiosperm*. Kalyani Publishers, New Delhi.

- Vincent ER and Yamaguchi M. 1997. *World vegetables*. 2nd Ed. Chapman and Hall.

I. Course Title : Organic Vegetable Production

II. Course Code : VSC 511

III. Credit Hours : (1+1)

IV. Why this course ?

Organic vegetable farming is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. Organic farming has been simply defined as a production system working in partnership with nature to produce vegetable crops. The current trend towards increasing popularity of organically produced vegetables is relatively new. The objective of organic farming is to produce safer food and to keep the environment healthy. During the decade of nineties, the interest in organic farming began to creep into the mainstream consumer purchases. Currently, it appears to be an influx of business oriented producers into the organic production field. The increasing popularity of organic food among the elite societies is due to the belief that food produced with this system is free of pesticides and has greater nutritive value than conventionally produced food. The students of vegetable science need to have an understanding of organic vegetable farming technology.

V. Aim of the course

To elucidate principles, concepts and their applications in organic farming of vegetable crops

The course is constructed given as under: No.

Block	Unit
1. Organic vegetable production	1. Importance and principles 2. Organic production of vegetables 3. Managing soil fertility 4. Composting methods 5. Certification and export

VI. Theory

Unit I

Importance and principles—Importance, principles, perspective, concepts and components of organic farming in vegetable crops

Unit II

Organic production of vegetables—Organic production of vegetable crops, viz., Solanaceous, Cucurbitaceous, leguminous, okra, amaranth, curry leaf, drumstick, bread fruit, Cole, root and tuber crops

Unit III

Managing soil fertility—Managing soil fertility, mulching, raising green manure
crops, weed management in organic farming system; Crop rotation in organic production; Processing and quality control of organic vegetable produce

Unit IV

Composting methods—Indigenous methods of composting, Panchyagavvya, Biodynamics preparations and their application; ITKs in organic vegetable farming; Role of botanicals and bio-control agents in the management of pests and diseases in vegetable crops

Unit V

Certification and export—Techniques of natural vegetable farming, GAP and GMP- certification of organic products; Export- opportunity and challenges

VII. Practical

- Methods of preparation and use of compost, vermicompost, biofertilizers and biopesticides;
- Soil solarisation;
- Use of green manures;
- Waste management; Organic soil amendments in organic production of vegetablecrops;
- Weed, pest and disease management in organic vegetable production;
- Visit to organic fields and marketing centres.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

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

- Appreciate the scope and scenario of organic vegetable production in India
- Acquire knowledge about the organic vegetable production technology
- Adopting production of organic vegetable crops a s entrepreneur

X. Suggested Reading

Dahama AK. 2005. *Organic farming for sustainable agriculture*. 2nd Ed. Agrobios.

Gehlot G. 2005. *Organic farming; standards, accreditation certification and inspection*. Agrobios. Palaniappan SP and Annadorai K. 2003. *Organic farming, theory and practice*. Scientific publ.

Pradeepkumar T, Suma B, Jyothibhaskar and Satheesan KN. 2008. *Management of horticultural crops*. New India Publ. Agency.

Shivashankar K. 1997. *Food security in harmony with nature. 3rd IFOAMASIA,* Scientific Conf. 1- 4 December, UAS, Bangalore.

I. **Course Title : Production of Spice Crops**

II. **Course Code : VSC 512**

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

IV. **Why this course ?**

Spices are an important part of human history and played an important role in the development of most cultures around the world. Spice may be a seed, fruit, root, bark, or any other plant substance primarily used for flavouring, colouring, or preserving food. Spices are distinguished from herbs, whichare the leaves, flowers, or stems of plants used for flavouring or as a garnish. Many spices have antimicrobial properties, because of which why spices are more commonlyused in warmer climates, which have more infectious diseases, and use of spices is prominent in meat, which is predominantly susceptible to spoiling. The students of vegetable scienceneed to have an understanding of production technology of spices and their processing before supplying them to the market or further use.

V. **Aim of the course**

To impart basic knowledge about the importance and production technology of spices grown in India

The course is constructed given as under:

No.	Block	Unit
1.	Production of spice crops	1. Fruit spices 2. Bud and kernel spices 3. Underground spice crops 4. Seed spices 5. Tree spices

VI. **Theory**

Introduction and importance of spice crops- historical accent, present status (national and international), future prospects, botany and taxonomy, climatic and soil requirement, commercial cultivars/ hybrids, site selection, layout, sowing/ planting time and methods, seed rate and seed treatment, nutritional and irrigation requirement, intercropping, mixed cropping, intercultural operations, weed control, mulching, physiological disorders, harvesting, post-harvest management, plant protection measures, quality control and pharmaceutical significance of crops mentioned below:

Unit I

Fruit spices- Black pepper, small cardamom, large cardamom and allspice

Unit II

Bud and kernel- Clove and nutmeg

Unit III

Underground spices- Turmeric, ginger and garlic

Unit IV

Seed spices- Coriander, fenugreek, cumin, fennel, ajowain, dill and celery

Unit V

Tree spices- Cinnamon, tamarind, garcinia and vanilla

VII. Practical

- Identification of seeds and plants;
- Botanical description of plant;
- Preparation of spice herbarium;
- Propagation;
- Nursery raising;
- Field layout and method of planting;
- Cultural practices;
- Harvesting, drying, storage, packaging and processing;
- Value addition;
- Short term experiments on spice crops.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

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

- Appreciate the scope and scenario of production of spice crops in India
- Acquire knowledge about the production technology and processing of spice crops
- Adopting production of spice crops as entrepreneur

X. Suggested Reading

- Agarwal S, Sastry EVD and Sharma RK. 2001. *Seed spices: production, quality, export*. Pointer Publication.
- Arya PS. 2003. *Spice crops of India*. Kalyani.
- Bhattacharjee SK. 2000. *Hand book of aromatic plants*. Pointer

publications.

- Bose TK, Mitra SK, Farooqi SK and Sadhu MK. (Eds.). 1999. *Tropical horticulture*.Vol.I. Naya Prokash.
- Chadha KL and Rethinam P. (Eds.). 1993. *Advances in horticulture*. Vols. IX-X. *Plantation crops and spices*. Malhotra Publ. House.
- Gupta S. (Ed.). *Hand book of spices and packaging with formulae*. engineers India researchinstitute, New Delhi.
- Kumar NA, Khader P, Rangaswami and Irulappan I. 2000. *Introduction to spices, plantation crops, medicinal and aromatic plants*. Oxford and IBH.
- Nybe EV, Miniraj N and Peter KV. 2007. *Spices*. New India Publ. Agency.
- Parthasarthy VA, Kandiannan V and Srinivasan V. 2008. *Organic spices*. New India Publ. Agency.
- Peter KV. 2001. *Hand book of herbs and spices*. Vols. I-III. Woodhead Publ. Co. UK and CRC USA.
- Pruthi JS. (Ed.). 1998. *Spices and condiments*. National Book Trust
- Pruthi JS. 2001. *Minor spices and condiments- crop management and post harvest technology*. ICAR.
- Purseglove JW, Brown EG, Green CL and Robbins SRJ. (Eds.). 1981. *Spices*. Vols. I, II. Longman.
- Shanmugavelu KG, Kumar N and Peter KV. 2002. *Production technology of spices and plantationcrops*. Agrobios.
- Thamburaj S and Singh N. (Eds.). 2004. *Vegetables, tuber crops and spices*. ICAR.
- Tiwari RS and Agarwal A. 2004. *Production technology of spices*. International Book Distr. Co. Varmudy V. 2001. *Marketing of spices*. Daya Publ. House.

I. Course Title : Processing of Vegetable Crops

II. Course Code : VSC 513

III. Credit Hours : (1+1)

IV. Why this course ?

In India, agriculture is the basis of economy. Agricultural industries and related activities, which can be termed as agriculturally based vegetable processing, can account for a considerable proportion of their output. Both established and planned vegetable processing projects aim at solving a very clearly identified developmental problems. The growers sustain substantial losses due to insufficient demand in the market, weak infrastructure, poor transportation and perishable nature of the vegetable crops. During the postharvest glut, the loss is considerable and often some of the produce are fed to the animals or allowed to decay. Even the established vegetable canning industries or small/ medium scale processing centres suffer huge loss due to erratic supplies since the growers like to sell their produce in the open market directly to the consumers, or the produce may not be of enough high quality to process but it might be good enough for the table use, meaning that processing is seriously underexploited. The main objective of vegetable processing is to supply wholesome, safe, nutritious and acceptable food to the consumers throughout the year. Vegetable processing also aims to replace imported products

like squash, jams, tomato sauces, pickles, etc., besides earning foreign exchange by exporting finished or semi-processed products. The students of vegetable science need to have an understanding of vegetable processing.

V. Aim of the course

To educate the students about the principles and practices of processing in vegetablecrops

The course is constructed given as under:

No.	Block	Unit
1.	Processing of vegetable crops	I Present status II Spoilage and biochemical changes III Processing equipments IV Quality control V Value addition

VI. Theory

Unit I

Present status—Present status and future prospects of vegetable preservation industry in India

Unit II

Spoilage and biochemical changes—Spoilage of fresh and processed vegetable produce; biochemical changes and enzymes associated with spoilage of vegetable produce; Principal spoilage organisms, food poisoning and their control measures; Role of microorganisms in food preservation

Unit III

Processing equipments—Raw material for processing; Primary and minimal processing; Processing equipments; Layout and establishment of processing industry; FPO licence; Importance of hygiene; Plant sanitation

Unit IV

Quality control—Quality assurance and quality control, TQM, GMP; Food standards- FPO, PFA, etc.; Food laws and regulations; Food safety- hazard analysis and critical control points (HACCP); Labeling and labeling act and nutrition labeling

Unit V

Value addition—Major value added vegetable products; Utilization of byproducts of vegetable processing industry; Management of processing industry waste; Investment analysis; Principles and methods of sensory evaluation of fresh and processed vegetables

VII. Practical

- Study of machinery and equipments used in processing of vegetable produce;
- Chemical analysis for nutritive value of fresh and processed vegetable;
- Study of different types of spoilage in fresh as well as processed vegetable produce;
- Classification and identification of spoilage organisms;
- Study of biochemical changes and enzymes associated with spoilage;
- Laboratory examination of vegetable products;
- Sensory evaluation of fresh and processed vegetables;
- Study of food standards- National, international, CODEX Alimentarius;
- Visit to processing units to study the layout, hygiene, sanitation and waste management.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedures
- Group discussion

IX. Learning outcome

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

- Appreciate the scope and scenario of vegetable processing in India
- Acquire knowledge about the processing technology of vegetable crops
- Adopting processing products of vegetable crops at small or medium scale
- Adopt processing of vegetable crops as entrepreneur

X. Suggested Reading

- Arthey D and Dennis C. 1996. *Vegetable processing*. Blackie/Springer-Verlag. Chadha DS. 2006. *The Prevention of food adulteration act*. Confed. of Indian Industry. Desrosier NW. 1977. *Elements and technology*. AVI Publ. Co.
- FAO. 1997. *Fruit and Vegetable processing*. FAO.
- FAO. *CODEX Alimentarius: Joint FAO/ WHO food standards*

programme. 2nd Ed. Vol. VB. *tropical fresh fruits and vegetables*. FAO.

- FAO. *Food quality and safety systems- training manual on food hygiene and haccp*. FAO. Fellow's P. 1988. Food processing technology. Ellis Horwood International.
- Frazier WC and Westhoff DC. 1995. *Food microbiology*. 4th Ed. Tata McGraw Hill.
- Giridharilal GS Siddappa and Tandon GL. 1986, *Preservation of fruits and vegetables*. ICAR. Gisela J. 1985. *Sensory evaluation of food- theory and practices*. Ellis Horwood.
- Graham HD. 1980. *Safety of foods*. AVI Publ. Co.
- Hildegrade H and Lawless HT. 1997. *Sensory evaluation of food*. CBS. Joslyn M and Heid *Food processing operations*.AVI Publ. Co.
- Mahindru SN. 2004. *Food safety: concepts and reality*. APH Publ. Corp.
- Ranganna S. 1986. *Handbook of analysis and quality control for fruit and vegetable products*. 2nd Ed. Tata-McGraw Hill.
- Shapiro R. 1995. *Nutrition labeling handbook.* Marcel Dekker.
- Srivastava RP and Kumar S. 2003. *Fruit and vegetable preservation: principles and practices*. 3rd Ed. International Book Distri. Co.
- Tressler and Joslyn MA. 1971. *Fruit and vegetable juice processing technology*. AVI Publ. Co. Verma LR and Joshi VK. 2000. *Postharvest technology of fruits and vegetables: handling, processing, fermentation and waste management*. Indus Publ. Co.

I. **Course Title : Postharvest Management of Vegetable Crops**

II. **Course Code : VSC 514**

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

IV. **Why this course ?**

Vegetables are highly perishable crops as they have great quantity andquality loss after harvest. Hence, they require integrated approach to arrest their spoilage, which causes tonnes of vegetable produce annually. Lack of postharvest awareness and inadequacy of equipments are the major problems in postharvest chain, which lead to a serious post-harvest loss in the developing countries every year. A comprehensive understanding of postharvest factors causing deterioration is necessary to overcome these challenges. Pre and postharvest management such as use of improved varieties, good cultural practices, good pre and postharvest handling practices, management of temperature, relative humidity and storage atmosphere according to crop requirement, use of permitted chemicals, design of appropriate packaging material and storage structures are some of the control measures usedin reducing postharvest losses, therefore, this course was customized.

V. Aim of the course

To facilitate deeper understanding of principles and to acquaint the student with proper handling and management technologies of vegetable crops for minimizing the post-harvest losses

The course is organized as follows:

No.	Blocks	Units
1.	Post-harvest management of vegetable crops	I Importance and scope II Maturity indices and biochemistryIII Harvesting and losses factors IV Packinghouse operations V Methods of storage

VI. Theory

Unit I

Importance and scope—Importance and scope of post-harvest management of vegetables

Unit II

Maturity indices and biochemistry—Maturity indices and standards for different vegetables; Methods of maturity determination; Biochemistryof maturity and ripening; Enzymatic and textural changes; Ethylene evolution and ethylene

management; Respiration and transpiration along with their regulation methods

Unit III

Harvesting and losses factors—Harvesting tools and practices for specific market requirement; Postharvest physical and biochemical changes; Preharvest practices and other factors affecting postharvest losses

Unit IV

Packing house operations—Packing house operations; Commodity pretreatments chemicals, wax coating, precooling and irradiation; Packaging of vegetables, prevention from infestation, management of postharvest diseases and principles of transportation

Unit V

Methods of storage—Ventilated, refrigerated, modified atmosphere and controlled atmosphere storage, hypobaric storage and cold storage; Zero-energy cool chamber,storage disorders like chilling injury in vegetables

VII. Practical

- Studies on stages and maturing indices;
- Ripening of commercially important vegetable crops;
- Studies of harvesting, pre-cooling, pre-treatments, physiological disorders- chilling injury;
- Improved packaging;
- Use of chemicals for ripening and enhancing shelf life of vegetables;
- Physiological loss in weight, estimation of transpiration, respiration rate and ethylene release;
- Storage of important vegetables;
- Cold chain management;
- Visit to commercial packinghouse, cold storage and control atmosphere storage.

VIII. Teaching Methods/ Activities

- Classroom lectures including ppt.
- Students group discussion
- Individual or group assignments (writing and speaking)
- Presentation of practical handwork

IX. Learning outcome

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

- Regulation of postharvest losses by using chemicals and growth regulators
- Pre and postharvest treatments for extending shelf life of vegetable crops
- Packinghouse operations for extending the shelf life of vegetable crops
- Successful storage of vegetable crops

X. Suggested Reading

- Chadha KL and Pareek OP. 1996. *Advances in horticulture*. Vol. IV. Malhotra Publ. House. Chattopadhyay SK. 2007. *Handling, transportation and storage of fruit and vegetables*. Gene- Tech books, New Delhi.
- Haid NF and Salunkhe SK. 1997. *Postharvest physiology and handling of fruits and vegetables*. Grenada Publ.
- Mitra SK. 1997. *Postharvest physiology and storage of tropical and sub-*

tropical fruits. CABI. Paliyath G, Murr DP, Handa AK and Lurie S. 2008. *Postharvest biology and technology of*

- *Fruits, vegetables and flowers*. Wiley-Blackwell, ISBN: 9780813804088.
- Ranganna S. 1997. *Handbook of analysis and quality control for fruit and vegetable products*. Tata McGraw-Hill.
- Stawley JK. 1998. *Postharvest physiology of perishable plant products*. CBS publishers. Sudheer KP and Indira V. 2007. *Postharvest technology of horticultural crops*. New India Publ. Agency.2) Blackwell Publishing Ltd, Oxford, UK. ISBN: 9781118654040.
- Verma LR and Joshi VK. 2000. *Postharvest technology of fruits and vegetables: handling, processing, fermentation and waste management*. Indus Publishing Company, New Delhi, India. ISBN 8173871086.
- Willis R, McGlassen WB, Graham D and Joyce D. 1998. *Postharvest: An introduction to the physiology and handling of fruits, vegetables and ornamentals*. CABI.
- Wills RBH and Golding J. 2016. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*, CABI Publishing, ISBN 9781786391483.
- Wills RBH and Golding J. 2017. *Advances in postharvest fruit and vegetable technology*, CRC Press, ISBN 9781138894051.

Course Title with Credit Load for Ph.D. in Vegetable Science

Course Code	Course Title	Credit Hours
	Major Courses (12 Credits)	
VSC 601*	Recent Trends in Vegetable Production	3+0
VSC 602*	Advances in Breeding of Vegetable Crops	3+0
VSC 603	Abiotic Stress Management in Vegetable Crops	2+1
VSC 604	Seed Certification, Processing and Storage of Vegetable Seeds	2+1
VSC 605	Breeding for Special Traits in Vegetable Crops	2+0
VSC 606	Biodiversity and Conservation of Vegetable Crops	2+1
VSC 607	Biotechnological Approaches in Vegetable Crops	2+1
VSC 608	Advanced Laboratory Techniques for Vegetable Crops	1+2
VSC 691	Doctoral Seminar I	0+1
VSC 692	Doctoral Seminar II	0+1
VSC 699	Doctoral Research	0+75
	Total Credits	100

*Compulsory among major courses

I. **Course Title** : **Recent Trends in Vegetable Production**

II. **Course Code** : **VSC 601**

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

IV. **Why this course ?**

India is the second largest producer of vegetables in the world, next only to China. Most challenging task is to ensure for continuous and enough supply of vegetables to growing population. Urban areas are experiencing substantial increase in population; this growth is accompanied with change in food habits and rising concerns for food quality. Here, food quality refers to the optimum levels of the nutrition in the food along with the minimized amount of the chemical (pesticides/ fertilizers) residues used in the production of the vegetables. Vegetables are being highly seasonal, perishable are also capital and labour intensive and need care in handling and transportation. Environmental stress (climate change) and shortage of water and land resources are major constraints haunting the production. Though the advances in science and information technology has resulted in more comfortable world with global linkages, these advances has led to changes in production practices. Thus, the students of vegetable science need to have an understanding of recent trends in production technology of vegetable crops and their management.

V. **Aim of the course**

To keep abreast with latest developments and trends in production technology of vegetable crops.

The course is constructed given as under:

No.	Block	Unit
1	Recent trends in vegetable	1. Solanaceous crops production 2. Cole crops 3. Okra, onion, peas and beans, amaranth anddrumstick. 4. Root crops and cucurbits 5. Tuber crops

VI. **Theory**

Present status and prospects of vegetable cultivation; nutritional, antioxidant and medicinal values; climate and soil as critical factors in vegetable production; choice of varieties; Hi-tech nursery management; modern concepts in water and weed management; physiological basis of growth, yield and quality as influenced by chemicals and growth regulators; role of organic manures, inorganic fertilizers, micronutrients and biofertilizers; response of genotypes to low and high nutrient management, nutritional deficiencies/ disorders and correction methods; different cropping systems; mulching; Protected cultivation of vegetables, containerized culture for year round vegetable production; low cost polyhouse; nethouse production; crop modelling, organic gardening; vegetable production for pigments, processing of:

Unit I

Solanaceous crops: Tomato, brinjal, chilli, sweet pepper and potato.

Unit II

Cole crops: Cabbage, cauliflower and knol-khol, sprouting broccoli.

Unit III

Okra, cowpea, onion, peas and beans, amaranth and drumstick.

Unit IV

Root crops and cucurbits: Carrot, beet root, turnip and radish and cucurbits

Unit V

Tuber crops: Sweet potato, Cassava, elephant foot yam, Dioscorea and taro.

VI. **Teaching Methods/ Activities**

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Group discussion

VII. Learning outcome

After successful completion of this course, the students are exposed to:

- Acquire the knowledge about recent trends in production technology of vegetablecrops

VIII. Suggested Reading

- Bose TK and Som NG. 1986. *Vegetable crops of India*. Naya prokash.
- Bose TK, Kabir J, Maity TK, Parthasarathy VA and Som MG. 2003. *Vegetable crops*. Vols. I-III. Naya Udyog.
- Brewster JL. 1994. *Onions and other vegetable alliums*. CABI.
- Chadha KL and Kalloo G (Eds.). 1993-94. *Advances in horticulture* Vols. V-X. Malhotra Publ. House.
- Chadha KL (Ed.). 2002. *Hand book of horticulture*. ICAR.
- Chauhan DVS (Ed.). 1986. *Vegetable production in India*. Ram prasad and Sons.
- Fageria MS, Choudhary BR and Dhaka RS. 2000. *Vegetable crops: production technology*. Vol. II. Kalyani.
- FFTC. *Improved vegetable production in Asia*. Book Series No. 36.
- Ghosh SP, Ramanujam T, Jos JS, Moorthy SN and Nair RG. 1988. *Tuber crops*. Oxford andIBH.
- Gopalakrishanan TR. 2007. *Vegetable crops*. New India Publ. Agency.
- Hazra P and Som MG. 2015. *Seed production and hybrid technology of vegetable crops*. Kalyani publishers, Ludhiana.
- Hazra P. 2016. *Vegetable science*. 2ndedn, Kalyani publishers, Ludhiana.
- Hazra P. 2019. *Vegetable production and technology*. New India publishing agency, New Delhi. Kallo G and Singh K. (Ed.). 2001. *Emerging scenario in vegetable research and development*. Research periodicals and Book Publ. House.
- Kurup GT, Palanisami MS, Potty VP, Padmaja G, Kabeerathuma S and Pallai SV. 1996. *Tropical tuber crops, problems, prospects and future strategies*. Oxford and IBH.
- Rana MK. 2008. *Olericulture in India*. Kalyani Publishers, New Delhi.
- Rana MK. 2008. *Scientific cultivation of vegetables*. Kalyani Publishers, New Delhi. *nutritive values*. Chapman and Hall.
- Saini GS. 2001. *A Text Book of oleri and flori culture*. Aman Publishing House.

- Salunkhe DK and Kadam SS. (Ed.). 1998. *Hand book of vegetable science and technology: production, composition, storage and processing*. Marcel Dekker.
- Shanmugavelu KG. 1989. *Production technology of vegetable crops*. Oxford and IBH. Sin MT and Onwueme IC. 1978. *The tropical tuber crops*. John Wiley and Sons.
- Singh DK. 2007. *Modern vegetable varieties and production technology*. International bookdistributing Co.
- Singh NP, Bhardwaj AK, Kumar A and Singh KM. 2004. *Modern technology on Vegetable production*. International book distr. Co.
- Singh PK, Dasgupta SK and Tripathi SK. 2006. *Hybrid vegetable development*. Internationalbook distr. Co.
- Singh SP. (Ed.). 1989. *Production technology of vegetable crops*. Agril. Comm. Res. Centre. Thamburaj S and Singh N. (Eds.). 2004. *Vegetables, tuber crops and spices*. ICAR. Thompson HC and Kelly WC. (Eds.). 1978. *Vegetable crops*. Tata McGraw-Hill.

I. Course Title : Advances in Breeding of Vegetable Crops

II. Course Code : VSC 602

III. Credit Hours : (3 +0)

IV. Why this course ?

The improvement of vegetable crops has until recently, been largely confined to conventional breeding approaches and such programmes rely on hybridization of plants which have desirable heritable characteristics and on naturally or artificially induced random mutations. The introduction of new genetic information can result in increased resistance to insect pest, diseases tolerance to environmental condition, improved quality, etc. The modern biotechnological tools like molecular assisted selection, double haploidy, genetic engineering, etc. can be of immense importance for rapid development of superior varieties with desirable qualitative and quantitative traits. Therefore, conventional breeding in conjunction with molecular biology has bright prospects of developing high yielding vegetable varieties with high nutraceuticals and bio active compounds suitable for fresh as well as processed market. The students of vegetable science who are having breeding as major subject need to have an understanding of recent technologies in vegetable crops.

V. Aim of the course

To impart knowledge on the recent research trends and advances in breeding of vegetable crops.

The course is constructed given as under:

No.	Block	Unit
1	Advances in Breeding of vegetable	I. Solanaceous crops and okracrops II. Cucurbits and Cole crops III. Legumes and leafy vegetables IV. Root crops and onion V. Tuber crops

III. Theory

Evolution, distribution, cytogenetics, Genetics and genetic resources, wild relatives, genetic divergence, hybridization, inheritance of qualitative and quantitative traits, heterosis breeding, plant idotype concept and selection indices, breeding mechanisms, pre breeding, mutation breeding, ploidy breeding, breeding for biotic and abiotic stresses, breeding techniques for improving quality and processing characters, bio-fortification, *in-vitro* breeding, marker assisted breeding, haploidy, development of transgenic.

Unit I

Solanaceous crops—Tomato, Brinjal, Hot Peeper, Sweet Pepper, Okra and Potato

Unit II

Cucurbits and Cole crops

Unit III

Legumes and leafy vegetables—Cowpea, Peas and Beans, Amaranth, Palak, Chenopods and Lettuce.

Unit IV

Root crops and onion—Carrot, Beetroot, Radish, Turnip, Onion

Unit V

Tuber crops—Sweet potato, Tapioca, Elephant foot yam, Colocasia, Dioscorea

IV. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Group discussion

V. Learning outcome

After successful completion of this course, the students are exposed to:

- Breeding objectives and trends
- Recent Adavnces in vegetable breeding

VI. Suggested Reading

- Allard RW. 1999. *Principle of plant breeding*. John Willey and Sons, USA.Basset MJ. (Ed.). 1986. Breeding vegetable crops. AVI Publ.
- Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa Publ. House.
- Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: Breeding and seed production*. Vol. I. Kalyani.
- Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.
- Hayes HK, Immer FR and Smith DC. 1955. *Methods of plant breeding*. McGraw-Hill.
- Hayward MD, Bosemark NO and Romagosa I. (Eds.). 1993. *Plant Breeding-principles and prospects*. Chapman and Hall.
- Hazra P and Som MG. 2015. *Vegetable science* (Second revised edition), Kalyani publishers, Ludhiana, 598 p
- Hazra P and Som MG. 2016. *Vegetable seed production and hybrid technology* (Second revised edition), Kalyani Publishers, Ludhiana, 459 p
- Kalloo G. 1988. *Vegetable breeding* (Vol. I, II, III). CRC Press, Fl, USA.
- Kalloo G. 1998. *Vegetable breeding*. Vols. I-III (Combined Ed.). Panima Edu. Book Agency. Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. Agro Botanical Publ.
- Paroda RS and Kalloo G. (Eds.). 1995. *Vegetable research with special reference to hybridtechnology in Asia-Pacific Region*. FAO.
- Peter KV and Pradeepkumar T. 2008. *Genetics and breeding of vegetables.* Revised, ICAR.
- Peter KV and Hazra P. (Eds). 2012. *Hand book of vegetables*. Studium press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 678p.
- Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume II.Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509p.
- Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume III.Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 634p.
- Rai N and Rai M. 2006. *Heterosis breeding in vegetable crops*. New India Publ. Agency.
- Ram HH. 1998. *Vegetable breeding: principles and practices*. Kalyani Publishers, New Delhi. Simmonds NW. 1978. *Principles of crop improvement*. Longman. Singh BD. 1983. Plant Breeding. Kalyani Publishers, New Delhi.
- Singh BD. 1983. *Plant breeding.* Kalyani Publishers, New Delhi.

- Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. International Book Distributing Co.
- Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

I. Course Title : Abiotic Stress Management in Vegetable Crops

II. Course Code : VSC 603

III. Credit Hours : (2+1)

IV. Why this course ?

Improvement of vegetable crops has traditionally focused on enhancing a plant's ability to resist diseases or insects. That is evidenced by the large number of disease- or insect-resistant cultivars or germplasm released and used. Research on crop resistance or tolerance to abiotic stresses (heat, cold, drought, flood, salt, pH, etc.) has not received much attention. However, that is changing as a result of the research and publicity of global warming. The changing environments pose serious and imminent threats to vegetable production and place unprecedented pressures on the sustainability of vegetable production. The challenges and opportunities coexist for our dynamic and resilient industry. In addition to conserving resources, weshould mitigate abiotic stresses and adapt to the warming planet. The studentof vegetable science need to know the different methods involved to mitigate the abiotic stress in vegetable crops.

V. Aim of the course

To update knowledge on the recent research trends in the field of abiotic stressmanagement in vegetables.

- To teach management practices to mitigate abiotic stress in vegetable cropsThe course is constructed given as under:

VI.

No.	Block	Unit
1	Abiotic stress management in vegetable crops	I Environmental stress II Mechanism and measurements of tolerance III Soil-plant-water relations IV Techniques of vegetable growing under highstress condition V Use of chemicals

VII. Theory

Unit I

Environmental stress—its types, soil parameters including pH, classification of vegetable crops based on susceptibility and tolerance to various types of stress.

Unit II

Mechanism and measurements—tolerance to drought, water logging, soil salinity,frost and heat stress in vegetable crops.

Unit III

Soil-plant-water relations—under different stress conditions in vegetable cropsproduction and their management practices.

Unit IV

Techniques of vegetable growing under water deficit, water logging, salinity andsodicity.

Unit V

Use of chemicals—techniques of vegetable growing under high and low temperatureconditions, use of wild species, chemicals and antitranspirants in alleviation of different stresses.

VIII. Practical

- Identification of susceptibility and tolerance symptoms to various types of stressin vegetable crops;
- Measurement of tolerance to various stresses in vegetable crops;
- Short term experiments on growing vegetable under water deficit,water logging, salinity and sodicity, high and low temperature conditions;
- Use of chemicals for alleviation of different stresses.

IX. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedure
- Group discussion

X. Learning outcome

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

- Acquire the knowledge about effect of different abiotic stresses on vegetables
- Methods to mitigate abiotic stress in vegetables

XI. Suggested Reading

- Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa Publ. House.
- Dwivedi P and Dwivedi RS. 2005. *Physiology of abiotic stress in plants*. Agrobios. Janick JJ. 1986. *Horticultural science*. 4th Ed. WH Freeman and Co.

- Kaloo G and Singh K. 2001. *Emerging scenario in vegetable research and development*. Researchperiodicals and book publ. house.
- Kaloo G. 1994.*Vegetable breeding*. Vols. I-III. Vedams eBooks.
- Lerner HR. (Eds.). 1999. *Plant responses to environmental stresses*. Marcel Decker. Maloo SR. 2003. *Abiotic stresses and crop productivity*.Agrotech Publ. Academy.
- Narendra T. *et al*. 2012. *Improving crops resistance to abiotic stress*. Wiley and Sons.US. Peter KV and Pradeep Kumar T. 2008. *Genetics and breeding of vegetables*. (Revised Ed.). ICAR. Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* volume II.Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509p.
- Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* volume III. Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 634p.Ram HH. 2001. *Vegetable breeding*. Kalyani.
- Rao NK. (Eds.). 2016. *Abiotic stress physiology of horticultural crops*. Springer publication.

I. Course Title : Seed Certification, Processing and Storage of Vegetable Seeds

II. Course Code : VSC 604

III. Credit Hours : (2+1)

IV. Why this course ?

Every farmer should able to access healthy seeds which are genetically pure, with high seed vigour and good germination percentage. Timely availability of goodquality seeds at reasonable price ensures good yield and profit to the farmers. The seeds plays a vital role in agriculture and acts as a carrier of the genetic potential of varieties. Quality seed production which follows efficient certification procedures plays a major role in the increase of food production of our country. To ensure this, the Government has prescribed standards and has brought in seed production techniques, testing, certification and marketing procedures through the Seeds Act, 1966. In the current scenario, the demand for good quality certified seeds far exceed the availability in the market. This manual provides details about productionandprocurement of good quality seeds.

V. Aim of the course

To impart the knowledge on seed certification, processing and storage of vegetable seeds.

VI. Theory

Unit I

Seed certification, history, concepts and objectives, seed certification agency, phases of seed certification, Indian Minimum seed Certification standards, Planning and management of seed certification programmes.

Unit II

Principles and procedures of field inspection, seed sampling, testing and granting certification, OECD certification Schemes.

Unit III

Principles of seed processing, Methods of seed drying and cleaning, seed processing plant- Layout and design, seed treatment, seed quality enhancement, packagingand marketing.

Unit IV

Principles of Seed Storage, orthodox/ recalcitrant seeds, types of storage (open, bulk, controlled, germplasm, cryopreservation), factors affecting seed longevity in storage (Pre and post harvest factors).

Unit V

Seed aging and deterioration, maintenance of seed viability and vigor during storage, storage methods, storage structures, transportation and marketingof seeds.

VII. Practical

- General procedures of seed certification;
- Field inspection and standards;
- Isolation and rouging;
- Inspection and sampling at harvesting, threshing and processing;
- Testing physical purity, germination and moisture, grow-out test;
- Visit to regulatory seed testing and plant quarantine laboratories;
- Seed processing plants and commercial seed stores.

VIII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation individual or in group
- Hands on training of different procedure
- Group discussion

IX. Learning outcome

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

- Acquire the knowledge on seed certification
- Acquire the knowledge on seed processing and storage

X. Suggested Reading

- Agarwaal PK and Anuradha V. 2018. *Fundamentals of seed science* *and technology*. Brilliant publications, New Delhi.

- Basra AS. 2000. *Hybrid seed production in vegetables*. CRC press, Florida, USA.
- Bench ALR and Sanchez RA. 2004. *Handbook of seed physiology*. Food products press, NY/ London.
- Chakraborty SK, Prakash S, Sharma SP and Dadlani M. 2002. *Testingof distinctiveness, uniformity and stability for plant variety protection*.IARI, New Delhi
- Copland LO and McDonald MB. 2004. *Seed science and technology*, Kluwer academic press. Fageria MS, Arya PS and Choudhry AK. 2000. *Vegetable crops: breeding and seed production* Vol 1. Kalyani publishers, New Delhi.
- George RAT. 1999. *Vegetable seed production* (2nd Edition). CAB International.
- Hazra P and Som MG. 2016. *Vegetable seed production and hybrid technology* (Second revised edition), Kalyani publishers, Ludhiana, 459p
- Kalloo G, Jain SK, Vari AK and Srivastava U. 2006. *Seed: A global perspective*. Associated publishing company, New Delhi.
- Singhal NC. 2003. *Hybrid seed production*. Kalyani publishers, New Delhi.

I. Course Title : Breeding for Special Traits in Vegetable Crops

II. Course Code : VSC 605

III. Credit Hours : (2+0)

IV. Why this course ?

Many epidemiological studies reveal that people having a high level of consumptionof vegetables presents a better health and lower risk of chronic diseases, including cardiovascular diseases and different types of cancer. Vegetables contain many bioactive compounds and represent a major source of antioxidants and other compounds that are beneficial to human health. Consumers are increasingly demanding vegetables with bioactive properties that contribute to maintaining a good health and preventing diseases. In consequence, breeding programmes in vegetables are increasingly considering the content in bioactive compounds as a major breeding objective. In this way, there is an increasing number of breeding programmes and scientific studied aimed at improving the content in bioactive compounds of vegetables, and the trend seems that will continuingin the coming years. In this respect, the particular course has been designed for students of Vegetable Science department.

V. Aim of the Course

To impart knowledge on recent developments in breeding for improved nutritional quality in important vegetable crops

VI. Theory

Important nutrient constituents in vegetables and their role in human diet. Genetics of nutrients. Genetic and genomic resources for improving quality traits in vegetables, breeding strategies for developing varieties with improved nutrition for market and industrial purposes. Molecular and biotechnological approaches in breeding suitable cultivars of different crops for micronutrients and color content.

Unit I

Brassica group, carrot and beetroot.

Unit II

Tomato, brinjal, peppers and potato.

Unit III

Green leafy vegetables, Legume crops and okra.

Unit IV

Cucurbitaceous vegetable crops and edible Alliums.

Unit V

Biofortification in vegetable crops, genetic engineering for improvement of quality traits in vegetable crops, bioavailability of dietary nutrients from improved vegetable crops and impact on micronutrient malnutrition, achievements and future prospects in breeding for quality traits in vegetables.

VII. Teaching Methods/ Activities

- Classroom Lectures
- Assignment (written and speaking)
- Student presentation
- Hands on training of different procedure
- Group discussion

VIII. Learning outcome

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

- Know about various special characters of vegetables
- The recent breeding methods to achieve special characters in vegetables

IX. Suggested Reading

- Allard RW. 1999. *Principles of plant breeding*. John Wiley and Sons. Basset MJ. (Ed.). 1986. *Breeding vegetable crops*. AVI Publ.
- Dhillon BS, Tyagi RK, Saxena S and Randhawa GJ. 2005. *Plant genetic resources: horticultural crops*. Narosa Publ. House.
- Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable crops: Breeding and seed production*. Vol. I. Kalyani.
- Gardner EJ. 1975. *Principles of genetics*. John Wiley and Sons.
- Hayes HK, Immer FR and Smith DC. 1955. *Methods of plant breeding*. McGraw-Hill.
- Hayward MD, Bosemark NO and Romagosa I. (Eds.). 1993. *Plant*

Breeding-principles and prospects. Chapman and Hall.

- Hazra P and Som MG. 2015. *Vegetable science* (Second revised edition), Kalyani publishers, Ludhiana, 598p.edition), Kalyani Publishers, Ludhiana, 459p
- Kalloo G. 1988. *Vegetable breeding*. Vols. I-III. CRC Press.
- Kalloo G. 1998. *Vegetable breeding*. Vols. I-III (Combined Ed.). Panima Edu. Book Agency. Kumar JC and Dhaliwal MS. 1990. *Techniques of developing hybrids in vegetable crops*. Agro Botanical Publ.
- Paroda RS and Kalloo G. (Eds.). 1995. *Vegetable research with special reference to hybridtechnology in Asia-Pacific Region*. FAO.
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- Peter KV and Hazra P. (Eds). 2015. *Hand book of vegetables* Volume II.Studium Press LLC, P.O. Box 722200, Houston, Texas 77072, USA, 509p.
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- Simmonds NW. 1978. *Principles of crop improvement*. Longman. Singh BD. 1983. Plant Breeding. Kalyani Publishers, New Delhi.
- Singh PK, Dasgupta SK and Tripathi SK. 2004. *Hybrid vegetable development*. International Book Distributing Co.
- Swarup V. 1976. *Breeding procedure for cross-pollinated vegetable crops*. ICAR.

I. Course Title : Biodiversity and Conservation of Vegetable Crops

II. Course Code : VSC 606

III. Credit Hours : (2+1)

IV. Why this course ?

The availability of pertinent gene pool is of utmost importance to mitigate adverse climate and to counter diseases and pests. In addition, specific gene sources (germplasm) would always be necessary to develop superior genotypes. Considering the importance of conserving biodiversity in vegetable crops for future use, the course has been designed.

V. Aim of the course

To understand the status and magnitude of biodiversity and strategies in germplasm conservation of vegetable crops.

The course is organised as follows:

No.	Blocks	Units
1	Biodiversity and conservation of vegetable crops	I General Aspects: Issues, Goals and Current Status II. Germplasm Conservation: Collection, Maintenance and Characterization III. Regulatory Horticulture: Germplasm Exchange, Quarantine and Intellectual Property Rights

VI. Theory

Unit I

General aspects: issues, goals and current status: Biodiversity and conservation; issues and goals- needs and challenges; present status of gene centres; world's major centres of fruit crop domestication; current status of germplasm availability/ database of fruit crops in India

Unit II

Germplasm conservation: collection, maintenance and characterization: Exploration and collection of germplasm; sampling frequencies; size and forms of fruit and nut germplasm collections; active and base collections. Germplasm conservation- in situ and ex situ strategies, on farm conservation; problem of recalcitrance- cold storage of scions, tissue culture, cryopreservation, pollen and seed storage.

Unit III

Regulatory horticulture: Germplasm exchange, quarantine and intellectual property rights germplasm exchange, quarantine and intellectual property rights regulatory horticulture, inventory and exchange of fruit and nut germplasm, plant quarantine, phytosanitary certification, detection of genetic constitution of germplasm and maintenance of core collection. IPRs, Breeder's rights, Farmer's rights, PPVandFR Act. GIS and documentation of local biodiversity, Geographical indications, GIS application in horticultural mapping and spatial analyses of field data; benefits of GI protection; GI tagged fruit varieties in India.

VII. Practical

- Documentation of germplasm- maintenance of passport data and other records ofaccessions;
- Field exploration trips and sampling procedures;

- Exercise on *ex situ* conservation – cold storage, pollen/ seed storage
- Cryopreservation;
- Visits to national gene bank and other centers of PGR activities;
- Detection of genetic constitution of germplasm;
- Germplasm characterization using a standardised DUS test protocol;
- Special tests with biochemical and molecular markers.

VIII. Teaching Methods/ Activities

- Class room lectures
- Laboratory/ field practicals
- Student seminars/ presentations
- Field tours/ demonstrations
- Assignments

IX. Learning outcome

- The student would be expected to learn about the significance of germplasm
- Various strategies to conserve it in the present context.

X. Suggested Reading

- Dhillon BS, Tyagi RK, Lal A and Saxena S. 2004. *Plant genetic resource management. – horticultural crops*. Narosa publishing house, New Delhi.
- Engles JM, Ramanath RV, Brown AHD and Jackson MT. 2002. *Managing plant genetic resources*, CABI, Wallingford, UK.University Press, USA.
- Hancock J. 2012. *Plant evolution and the origin of crops species*. CAB International.
- Jackson M, Ford-Lloyd B and Parry M. 2014, *Plant genetic resources and climate change*. CABI, Wallingford, UK
- Moore JN and Ballington JR. 1991. *Genetic resources of temperate Fruit and nut crops*. ISHS,Belgium.
- Peter KV. 2008. *Biodiversity of horticultural crops*. Vol. II. Daya Publ. House, Delhi. Peter KV. 2011. *Biodiversity in horticultural crops*. Vol.III. Daya Publ. House, Delhi.
- Rajasekharan PE, Rao V and Ramanatha V. 2019. *Conservation and utilization of horticultural genetic resources*. Springer.
- Rana JC and Verma VD. 2011. *Genetic resources of temperate minor fruits (indigenous andexotic*). NBPGR, New Delhi.
- Sthapit *et al*. 2016. *Tropical fruit tree diversity (good practices for in situ and ex situ conservation*). Bioversity international. routledge, Taylor and Francis Group.

- Virchow D. 2012. *Conservation of genetic resources*, Springer Verlag, Berlin

I. **Course Title : Biotechnological Approaches in Vegetable Crops**

II. **Course Code : VSC 607**

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

IV. **Why this course ?**

Biotechnology is a rapidly developing area of contemporary science. It can bring new ideas, improved tools and novel approaches to the solution of some persistent, seemingly intractable problems in vegetable production. Giventhe pressing need to enhance and stabilize the vegetable production in response to mounting population pressures and increasing awareness, there is an urgent need to technologies that will break traditional barriers

V. **Aim of the course**

To impart latest knowledge in biotechnical advancement in vegetable crops

The course is organised as follows:-

No.	Blocks	Units
1	Biotechnological approaches in Biotechnologyvegetable crops	I Importance and scope of II Somatic embryogenesis III Blotting techniques, DNA finger printing, IV Plant genetic engineering V Concepts and methods of next generationsequencing (NGS)

V. **Theory**

Unit I

Importance and scope of biotechnology – in vegetable crop improvement. *In-vitro* culture, micropropagation, anther culture, pollen culture, ovule culture, embryo culture, endosperm culture.

Unit II

Somatic embryogenesis – somaclonal variation and synthetic seed production, protoplast isolation, culture, manipulation and fusion. Somatic hybrids and cybrids and their application in vegetable improvement programme.

Unit III

Blotting techniques, DNA finger printing – Molecular markers/ DNA based markers and role. RFLP, AFLP, RAPD, SSR, SNPs, DNA probes. QTL mapping. MAS and its application in vegetable crop improvement. Allele mining by TILLING and Eco- TILLING.

Unit IV

Plant genetic engineering – Scope and importance, Concepts of cisgenesis, intragenesis and transgenesis. Gene cloning, direct and indirect methods of gene transfer. Role of RNAi based gene silencing in vegetable crop improvement. Bio-safety issue, regulatory issues for commercial approval.

Unit V

Concepts and methods of next generation sequencing (NGS)- Genome sequencing, transcriptomics, proteomics, metabolomics. Genome editing (ZFN, TALENS and CRISPER)

Crops

Solanaceous crops, cole crops, cucurbitaceous crops, root vegetables, garden pea,onion, potato and leafy vegetables

VII. Practical

- Micropropagation, Pollen- Ovule and Embryo culture- Synthetic seed production(2);
- *In-vitro* mutation induction, *in-vitro* rooting – hardening at primary and secondary nurseries (3);
- DNA isolation from economic vegetable crop varieties – Quantification and amplification (2);
- DNA and Protein profiling – molecular markers, PCR Handling (2);
- Vectors for cloning and particle bombardment (3);
- DNA fingerprinting of flower crop varieties (3);
- Project preparation for establishment of low, medium and high cost tissue culturelaboratories (1).

VIII. Teaching Methods/ Activities

- Class room lectures
- Laboratory/ field practicals
- Student seminars/ presentations
- Field tours/ demonstrations
- Assignments

IX. Learning outcome

The student would be expected to learn

- Different biotechnological tools
- NGS, genetic engineering

X. Suggested Reading

- Bajaj YPS. (Ed.). 1987. *Biotechnology in agriculture and forestry*. Vol.

XIX. Hitech and Micropropagation. Springer.

- Chadha KL, Ravindran PN and Sahijram L. (Eds.). 2000. *Biotechnology of horticulture andplantation crops*. Malhotra Publ. House.
- Debnath M. 2005. *Tools and techniques of biotechnology*. Pointer publication, New Delhi.
- Gorden H and Rubsell S. 1960. *Hormones and cell culture*. AB Book Publ.
- Keshavachandran R. 2007. *Recent trends in biotechnology of horticultural crops*. New India Publ. Agency.
- Keshavachandran R and Peter KV. 2008. *Plant biotechnology; tissue culture and gene transfer*. Orient and Longman, USA.
- Keshavachandran R. 2007. *Recent trends in biotechnology of horticultural crops*. New-India Publication Agency, New Delhi.
- Panopoulas NJ. (Ed.). 1981. *Genetic engineering in plant sciences*. Praeger Publ.
- Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK and Mohanadas S. 2001. *Biotechnology of horticultural crops.* Vols. I-III. Naya Prokash.
- Pierik RLM. 1987. *In-vitro culture of higher plants*. Martinus Nijhoff Publ.
- Prasad S. 1999. *Impact of plant biotechnology on horticulture*. 2nd Ed. Agro Botanica.
- Rout GR and Peter KV. 2018. *Genetic engineering of horticultural crops*. Academic Press Elsveer, USA.
- Sharma R. 2000. *Plant tissue culture*. Campus Books.
- Singh BD. 2010. *Biotechnology- expanding horizons*. Kalyani Publishers, New Delhi.
- Skoog Y and Miller CO. 1957. *Chemical regulation of growth and formation in plant tissue cultured in-vitro*. Attidel. II Symp. On biotechnology action of growth substance.
- Vasil TK, Vasi M, While DNR and Bery HR. 1979. *Somatic hybridization and genetic manipulation in plants, plant regulation and world agriculture*. Planum Press.

I. Course Title : Advanced Laboratory Techniques for Vegetable Crops

II. Course Code : VSC 608

III. Credit Hours : (1+2)

IV. Why this course ?

Accurate quality analysis of vegetables warrants stringent measurement protocols besides requisite instruments/ tools and laboratory facilities. Consequently, a specialized course is designed for imparting basic andapplied training on physical and biochemical assessment of the vegetable produce.

V. Aim of the course

To familiarize with the laboratory techniques for analysis of vegetable crops.The organisation of the course is as under:

No.	Blocks	Units
1	Advanced laboratory techniques for vegetable crops	I Safety measures and laboratory maintenance II Qualitative and quantitative analysis destructive and non-destructive analysismethods III Chromatographic and microscopic analysis IV Sensory analysis

VI. Theory

Unit I

Safety measures and laboratory maintenance – Safety aspects and upkeep of laboratory, sampling procedures for quantitative analysis, determination of proximate composition of horticultural produce. Standard solutions, determination of relative water content (RWC), physiological loss in weight (PLW), calibration and standardization of instruments, textural properties of harvested produce, TSS, Specific gravity, pH and acidity.

Unit II

Destructive and non-destructive analysis methods – Refractometry, spectrophotometry, non-destructive determination of colour, ascorbic acid, sugars, and starch in food crops.

Unit III

Chromatographic and microscopic analysis- basic chromatographic techniques, GC, HPLC, GCMS, Electrophoresis techniques, ultra filtration. Application of nuclear techniques in harvested produce. Advanced microscopic techniques, ion leakage as an index of membrane permeability, determination of biochemical components in horticultural produce.

Unit IV

Sensory analysis – Importance of ethylene, quantitative estimation of rate of ethylene evolution, using gas chromatograph (GC). Sensory analysis techniques, control of test rooms, products and panel.

VII. **Practical**

- Determination of moisture, relative water content and physiological loss in weight;
- Determination of biochemical components in horticultural produce;
- Calibration and standardization of instruments;
- Textural properties of harvested produce;
- Determination of starch index (SI);
- Specific gravity for determination of maturity assessment, and pH of produce;
- Detection of adulterations in fresh as well as processed products;
- Non-destructive determination of colour, ascorbic acid, vitamins, carotenoids,sugars and starch;
- Estimation of rate of ethylene evolution using gas chromatograph (GC);
- Use of advanced microscopes (fluorescent, scanning electron microscope, phasecontrast, etc.).

VIII. **Teaching Methods/ Activities**

- Class room Lectures
- Laboratory Practicals
- Student Seminars/ Presentations
- Field Tours/ Demonstrations
- Assignments

IX. **Learning outcome**

The students would be expected to develop skills and expertise on

- Upkeep of laboratories and handling of research instruments
- Principles and methods of various analysis

X. **Suggested Reading**

- AOAC International. 2003. *Official methods of analysis of AOAC international*. 17th Ed.
- Gaithersburg, MD, USA, association of analytical communities, USA.
- Clifton M and Pomeranz Y. 1988. *Food analysis – laboratory experiments.* AVI publication, USA.
- Linskens HF and Jackson JF. 1995. *Fruit analysis.* Springer.
- Leo ML. 2004. *Handbook of food analysis*, 2nd Ed. Vols. I-III, USA.
- Pomrenz Y and Meloan CE. 1996. *Food analysis – theory and practice*. CBS, USA.

- Ranganna S. 2001. *Handbook of analysis and quality control for fruit and vegetable products.* 2nd Ed. Tata-McGraw-Hill, New Delhi.
- Thompson AK. 1995, *Postharvest technology of fruits and vegetables.* Blackwell sciences. USA.

Selected Journals

Sr. No.	Name of the Journal	ISSN No.
1.	*American Journal of Horticultural Sciences*	0003-1062
2.	*American Potato Growers*	
3.	*American Scientst*	1545-2786
4.	*Annals of Agricultural Research*	9703179
5.	*Annual Review of Plant Physiology*	0066-4294
6.	*California Agriculture*	1097-0967
7.	*Haryana Journal of Horticultural Sciences*	0970-2873
8.	*HAU Journal of Research*	0379-4008
9.	*Horticulture Research*	2052-7276
10.	*HortScience*	2327-9834
11.	*IIVR Bulletins*	1462-0316
12.	*Indian Horticulture*	0019-4875
13.	*Indian Journal of Agricultural Sciences*	0019-5022
14.	*Indian Journal of Horticulture*	0974-0112
15.	*Indian Journal of Plant Physiology*	2662-2548
16.	*Journal of American Society for Horticutural Sciences*	0003-1062
17.	*Journal of Arecanut and Spice Crops*	
18.	*Journal of Food Science and Technology*	0975-8402
19.	*Journal of Plant Physiology*	0176-1617
20.	*Journal of Biology and Technology*	0925-5214
21.	*Postharvest Biology and Technology*	0925-5214
22.	*Scientia Horticulturae*	0304-4238
23.	*Seed Research*	2151-6146
24.	*Seed Science*	23171537
25.	*South Indian Horticulture*	0038-3473
26.	*Vegetable Grower*	2330-2321
27.	*Vegetable Science*	2455-7552

KERALA AGRICULTURAL UNIVERSITY
RESTRUCTURED AND REVISED SYLLABUS
FOR P.G. AND Ph.D. PROGRAMMES

FLORICULTURE AND LANDSCAPING

Course Title with Credit Load for M.Sc. (Hort.) in Floriculture and Landscaping

Course Code	Course Title	Credit Hours
	Major Courses (20 Credits)	
FLS 501*	Systematics of Ornamental Plants	2+1
FLS 502*	Breeding of Flower crops and Ornamental Plants	2+1
FLS 503*	Commercial Production of Cut Flowers	2+1
FLS 504*	Commercial Production of Loose Flowers	2+1
FLS 505*	Ornamental Gardening and Landscaping	2+1
FLS 506	Indoor Plants and Interiorscaping	1+1
FLS 507	Nursery Management in Ornamental Plants	2+1
FLS 508	Turfgrass Management	2+1
FLS 509	Value Addition in Floriculture	2+1
FLS 510	Protected Cultivation of Flower Crops	2+1
FLS 511	CAD for Landscaping	1+2
FLS 512	Seed Production in Flower Crops	1+1
	Minor Courses	08
	Supporting Courses	06
	Common compulsory courses	05
FLS 591	Master's Seminar	0+1
FLS 599	Master's Research	0+30
	Total Credits	**70**

*Compulsory among major courses

Course Code : **FLS 501**
Course Title : **Systematics of Ornamental Plants**
Credit Hours : **(2+1)**

Why this course?

Systematics of ornamental plants will give an in depth knowledge on nomenclature, description of genera, floral biology and use of molecular techniquesin systematics of flower crops and ornamental crops.

Aim of the course

To familiarize students about the taxonomy, classification, nomenclature and descriptors of different ornamental crops.

The course is organized as follows

No	Blocks	Units
1	Nomenclature	Unit 1: History, origin, hotspots, classification and nomenclature systems Unit 2: International Code, Identification features, descriptors. Unit 3: Red Book, Registration with NBPGR, PPVFRA
2	Families	Unit 1: Rosaceae, Asteraceae, Caryophyllaceae, Orchidaceae, Aracaeae, Liliacaeae, Unit 2: Acanthaceae, Palmaceae, Asparagaceae, Malvaceae, Fabaceae, Bignoniaceae, Apocynaceae, Moraceae, Rubiaceae, Nelumbonaceae , Nymphaeceae, Zingiberaceae, Heliconaceae, Oleaceae, Iridaceae.
3	Molecular techniques	Unit 1: Molecular techniques in modern systematics.

Theory

Block I: Nomenclature

Unit I: Nomenclature: History, origin, hotspots, classification and nomenclature systems.

Unit II: International systems: International Code, Treaties, International and National Organisations, Biodiversity Act, Identification features, descriptors.

Unit III: Red Book, Registration (NBPGR, PPVFRA, NBA).

Block 2: Families

Unit I: Families: Description and families and important genera Rosaceae, Asteraceae, Caryophyllaceae, Orchidaceae, Aracaceae, Liliacae.

Unit II: Acanthaceae, Palmaceae, Asparagaceae, Malvaceae, Oleaceae, Iridaceae, Fabaceae, Bignoniaceae, Apocynaceae, Moraceae, Rubiaceae, Nelumbonaceae, Nymphaeceae, Zingiberaceae, Heliconaceae

Block 3: Molecular techniques

Unit I: Molecular techniques in modern systematics.

Practical

- Different nomenclature systems of plants (2);
- Floral biology and taxonomic description of rose, chrysanthemum, orchids, carnation, gerbera, anthurium, marigold, tuberose, Jasmine, China aster, lilium, Lotus, Waterlily, Hibiscus (6);
- Cryopreservation and tissue culture repository (4);
- Molecular techniques (4).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and student presentation
- Hands on training of different procedures

Learning outcome

After successful completion of this course,

- The students will have an in depth knowledge of nomenclature, description of important genera and use of molecular techniques in systematics of flower crop

Suggested Reading

- Bhattacharya B and Johri BM. 2004. *Flowering Plants: Taxonomy and Phylogeny*. Narosa Publ. House, New Delhi, India. pp.753.
- Dutta AC. 1986. *A Class Book of Botany*. Oxford Univ. Press, Kolkata, India. Pandey BP. 2013. *Taxonomy of Angiosperms*. S. Chand & Co. pp. 608.
- Rajput CBS and Haribabu RS. 2014. *Citriculture*, Kalyani Publishers, New Delhi, India. Spencer RR, Cross R and Lumley P. 2007. *Plant Names*. 3rd Ed. *A Guide to Botanical Nomenclature*. CSIRO Publ., Australia., 176 p.
- Vasistha BB. 1998. *Taxonomy of Angiosperms*. Kalyani Publishers, New Delhi, India.

Course Code : **FLS 502**

Course Title : **Breeding of Flower Crops and Ornamental Plants**

Credit Hours : **(2+1)**

Why this course?

Breeding novel and desired varieties is very important for growth of floriculture Industry. Students should have a thorough understanding of principles of plant breeding, genetic mechanisms and breeding methods in ornamental crops for making improvement in these crops.

Aim of the course

To impart comprehensive knowledge about the principles and practices of breeding of ornamental plants.

The course is organized as follows

No	Blocks	Units
1	Principles of Plant Breeding	I. Principles of plant breeding II. Intellectual Property and Plant Breeders Rights III. Genetic mechanisms and inheritance
1	Breeding methods	I. Breeding methods II. Role of biotechnology

Theory

Block 1: Principles of Plant Breeding

Unit I: Principles of plant breeding: Principles of plant breeding; Origin, evolution, distribution, introduction, domestication and conservation of ornamental crops.

Unit II: Intellectual Property and Plant Breeders Rights: Introduction and initiatives in IPR and PBR of ornamental crops.

Unit III: Genetic mechanisms and inheritance: Breeding objectives, reproductive barriers (Male sterility, incompatibility) in major ornamental crops. Inheritance of important traits, Genetic mechanisms associated with flower colour, size, form, doubleness, fragrance, plant architecture, post- harvest life, abiotic and biotic stress tolerance/ resistance.

Block 2: Breeding methods

Unit I: Breeding methods: Breeding methods suitable for sexually, asexually propagated flower crops, self and cross pollinated crops- pedigree selection, backcross, clonal selection, polyploidy and mutation breeding, heterosis and F1 hybrids.

Unit II: Role of biotechnology: Role of biotechnology in improvement of flower crops including somaclonal variation, *in-vitro* mutagenesis, *in-vitro* selection, genetic engineering, molecular markers, etc.

Crops

Rose, chrysanthemum, carnation, gerbera, gladiolus, orchids, anthurium, lilium, marigold, jasmine, tuberose, dahlia, gaillardia, crossandra, aster, etc., Flowering annuals: petunia, zinnia, snapdragon, stock, pansy, calendula, balsam, dianthus, etc. Important ornamental crops like aglaonema, diffenbachia, hibiscus, bougainvillea, lotus, waterlily etc.

Practical

- Floral biology of important ornamental crops (2);
- Cytology and cytogenetics (2);
- Selfing and crossing procedures for important ornamental crops (2);
- Evaluation of hybrid progenies (2);
- Induction of mutants through physical and chemical mutagens (2);
- *In-vitro* selection, genetic engineering (2);
- Induction of polyploidy (2);
- DUS testing (2).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and student presentation
- Hands on training of different procedures

Learning outcome

After successful completion of course, the students are expected to have

- Thorough understanding of principles of plant breeding and genetic mechanismsin different ornamental plants and flowers.
- Application of different breeding methods for improvement of ornamental crops
- Develop the required skills in conventional and advanced breeding

Suggested Reading

- Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Pointer Publ., Reprint, 6 vols, pp. 2065.
- Bose TK and Yadav LP. 1989. *Commercial flowers.* Naya Prokash, Kolkata, India.
- Callaway DJ and Callaway MB. 2009. *Breeding Ornamental Plants*. Timber

Press. Revisededition, pp. 359.

- Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants*. Vol. XII, Parts 1 & 2. pp. 533, pp. 574. Malhotra Publ. House, New Delhi, India.
- Chadha KL and Choudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.
- Chaudhary RC. 1993. *Introduction to Plant Breeding.* Oxford & IBH Publ.
- De, L.C. and Bhattacharjee, S.K. 2011.Ornamental Crop Breeding. Avishkar Publishers, Distributors.pp454 Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Cut Flowers*. Kruger Brentt Publisher UK Ltd. pp.584.
- Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Traditionaland Loose Flowers*. Kruger Brentt Publisher UK Ltd.
- Singh BD. 2016. *Plant Breeding Principles and Methods.* Kalyani Publishers, New Delhi- Ludhiana, India.
- Vainstein A. (Ed). 2002. *Breeding for ornamental crops: Classical and Molecular Approaches*. Springer-Science-Business Media, B.V. Edition 1. pp. 392.
- Watts L. 1980. *Flower and Vegetable Plant Breeding*. Unilever Research, Sharnbrook, Bedford, UK. pp 182. Grower Books, London, UK.

Course Code : FLS 503

Course Title : Commercial Production of Cut Flowers

Credit Hours : (2+1)

Why this course?

Cut flowers are grown in a wide variety of environments and agroclimatic regions. The students of floriculture need to have an understanding of production and post harvest management of important cut flower crops on a commercial scale.

Aim of the course

To impart basic knowledge about the importance and production dynamics of cut flowers grown in India.

The course is organized as follows

No	Blocks	Units
1	Production management	I. Scope and scenario II. Growing environment III. Crop Management IV. Crop regulation
2	Post harvest management andmarketing	I. Post harvest management II. Marketing

Theory

Block 1: Production management

Unit I: Scope and scenario: National and International scenario, importance and scope of cut flower trade, constraints for cut flower production in India.

Unit II: Growing environment: Soli analysis, soil health card, Growing environment, open cultivation, protected cultivation, soil/ media requirements, land preparation, planting methods, influence of light, temperature, moisture, humidity and microclimate management ongrowth and flowering.

Unit III: Crop management: Commercial Flower production – Commercial varieties, water and nutrient management, fertigation, weed management, crop specific practices, ratooning, training and pruning, pinching, deshooting, bending, desuckering, disbudding. Use of growth regulators, physiological disorders and remedies, IPM and IDM.

Unit IV: Crop regulation: Flower forcing and year round/ offseason flower production through physiological interventions, chemical regulation, environmental manipulation.

Block 2: Post-harvest management and marketing

Unit I: Post harvest management: Cut flower standards and grades, harvest indices, harvesting techniques, post-harvest handling, Methods of delaying flower opening, Pre-cooling, pulsing, packing, storage and transportation.

Unit II: Marketing: Marketing, export potential, institutional support, Agri Export Zones, 100% Export Oriented units, Crop Insurance.

Crops

Rose, chrysanthemum, gladiolus, tuberose, carnation, gerbera, orchids, lilium, anthurium, china aster, alstroemeria, bird of paradise, heliconia, alpinia, ornamental ginger, dahlia, gypsophila, solidago, limonium, stock, cut greens and fillers.

Practical

- Identification of varieties (1);
- Propagation (2);
- Microclimate management (2);
- Training and pruning techniques (1);
- Pinching, deshooting, disbudding, desuckering (1);
- Practices in manuring, drip and fertigation, foliar nutrition, growth regulatorapplication (2);
- Harvesting techniques, post-harvest handling, cold chain (2);

- Economics, Project preparation for regionally important cut flowers, crop specificguidelines for project financing (NHB guidelines) (2);
- Visit to commercial cut flower units (2);
- Case studies (1).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and student presentation
- Hands on training of different procedures
- Exposure visits

Learning outcome

After successful completion of this course, the students are expected to–

- Understand the scope and scenario of floriculture
- A thorough understanding of production and post harvest management of flowercrops.
- Acquire the required skills to prepare project reports on different crops for financing.

Suggested Reading

- Arora JS. 2010. *Introductory Ornamental Horticulture*. Kalyani Publishers. 6th edition, pp.230.
- Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.
- Bose TK, Maiti, RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Prokash, Kolkata, India.
- Bose TK and Yadav LP. 1989. *Commercial Flowers*. Naya Prokash, Kolkata, India.
- Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants*. Vol.XII, Parts 1 & 2. pp. 533, pp. 574. Malhotra Publ. House, New Delhi, India.
- Chadha KL and Chaudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.
- Dole JM and Wilkins HF. 2004. *Floriculture-Principles and Species*. Prentice Hall. 2nd edition, pp. 1048.
- Larson RA. 1980. *Introduction to Floriculture*. New York Academic Press.

pp. 628.

- Laurie A and Rees VH. 2001. *Floriculture-Fundamentals and Practices*. Agrobios Publications, Jodhpur. pp.534.
- Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publications, Jodhpur. Randhawa GS and Mukhopadhyay A. 2001. *Floriculture in India*. Allied Publ. pp 660.
- Reddy S, Janakiram T, Balaji Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India.
- Singh AK. 2006. *Flower Crops: Cultivation and Management.* New India Publ. Agency, New Delhi, India. pp. 475.

Course Code : FLS 504
Course Title : Commercial Production of Loose Flowers
Credit Hours : (2+1)

Why this course?

Loose flowers are grown in a wide range of agroclimatic regions. The students of floriculture need to have an understanding of production and post harvest management of important loose flower crops.

Aim of the course

To impart basic knowledge about the importance and management of loose flowers grown in India.

The course is organized as follows

No	Blocks	Units
1	Production management	I. Scope and scenario II. Growing environment III. Crop management IV. Crop regulation
2	Post harvest management andmarketing	I. Post harvest management II. Marketing

Theory

Block 1: Production management

Unit I: Scope and scenario: Scope, scenario and importance of loose flowers, constraints and opportunities in loose flower production.

Unit II: Growing environment: Nursery management, pro-tray nursery under shade nets, soil and climate requirement, Field preparation, systems of planting.

Unit III: Crop management: Soli analysis, soil health card, water and nutrient management, weed management, training and pruning, special horticultural practices such as pinching and disbudding, use of growth regulators, physiological disorders and remedies, INM, IPM and IDM.

Unit IV: Crop regulation: Flower forcing and year round flowering, production for special occasions through physiological interventions, chemical regulation.

Block 2: Post harvest management and marketing

Unit I: Post harvest management: Harvest indices, harvesting techniques, post-harvest handling and grading, pre-cooling, packaging and storage.

Unit II: Marketing: Important local markets, Export potential, transportation and marketing, APMC and online trading, institutional support, CropInsurance.

Crops

Rose, jasmine, chrysanthemum, marigold, tuberose, china aster, crossandra, gaillardia, spider lily, hibiscus, nerium, barleria, celosia, gomphrena, Madar (*Calotropis gigantea*), nyctanthes (Harsingar), tabernaemontana (Chandni), lotus, water lily, michelia (Champa), gardenia, Ixora and balsam.

Practical

- Identification of species and varieties (1);
- Propagation and nursery management (1);
- Training and pruning techniques (1);
- Fertigation, foliar nutrition, growth regulator application (2);
- Crop protection (2);
- Pinching, disbudding, staking, harvesting techniques (1);
- Post-harvest handling, storage and cold chain (2);
- Project preparation for regionally important commercial loose flowers. crop specificguidelines for project financing (NHB guidelines) (2);
- Cost Economics (2);
- Exposure Visits to fields (2).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course, the students would have

- A thorough understanding of production and post harvest management of looseflowers.
- Develop the required skills on commercial production management

Suggested Reading

- Arora JS. 2010. *Introductory Ornamental Horticulture*. Kalyani Publi. 6th Edition, pp. 230. Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.
- Bose T K, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and landscaping*. Naya Prokash, Kolkata, India.
- Bose TK and Yadav LP. 1989. *Commercial Flowers*. Naya Prokash, Kolkata, India.
- Chadha KL and Bhattacharjee S K. 1995. *Advances in Horticulture: Ornamental Plants*. Vol. XII, Parts 1 & 2. pp. 533, pp. 574. Malhotra Publ. House, New Delhi, India.
- Chadha KL and Chaudhury B.1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India. Laurie A and Rees VH. 2001. *Floriculture-Fundamentals and Practices*. Agrobios Publ., Jodhpur. pp.534.
- Misra R.L. and Misra, S. 2017. *Commercial Ornamental Crops: traditional and Loose Flowers*. Kruger Brentt Publisher UK ltd. pp 584.
- Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publ., Jodhpur. Randhawa GS and Mukhopadhyay A. 2001. *Floriculture in India*. Allied Publ. pp 660.
- Sheela VL. 2008. *Flowers for Trade*. Horticulture Science Series, vol.10, pp. 392. New India Publ. Agency, New Delhi, India.

Course Code : **FLS 505**

Course Title : **Ornamental Gardening and Landscaping**

Credit Hours : **(2+1)**

Why this course?

Ornamental gardening and landscaping is an important course which gives a thorough understanding of different types of gardens and their components. The students need to imbibe the principles of landscaping and should develop skills for planning under different situations.

Aim of the course

Familiarization with principles and practices of landscaping.

The course is organized as follows:

No	Blocks	Units
1	Gardens and components	I. Styles and types of gardens II. Garden components III. Specialized gardens
2	Landscape planning	I. Principles and elements of landscaping II. Landscaping for different situations

Theory

Block 1: Gardens and components

Unit I: Styles and types of gardens: Historical background of gardening, Importance and scope of ornamental gardening, styles and types of gardens, formal andinformal style gardens. English, Mughal, Japanese, Persian, Spanish, Italian, French, Hindu and Buddhist gardens.

Unit II: Garden components: Garden components (living and non-living): arboretum, shrubbery, fernery, palmatum, arches and pergolas, edges and hedges, climbers and creepers, cacti and succulents, herbs, annuals, flower borders and beds, ground covers, carpet beds, colour wheels, clock garden, bamboo groves, bonsai; Non -living components like- path, garden gate, fencing, paving and garden features like fountains, garden seating, swings, lanterns, basins, bird baths, sculptures, waterfalls, bridge, steps, ramps, Lawn -genera and species, establishment and maintenance.

Unit III: Specialized gardens: Specialised gardens such as vertical garden, roof garden, terrace garden, water garden, sunken garden, rock garden, shade garden, temple garden, sacred gardens (with emphasis on nativeplants), Zen garden.

Block 2: Landscape planning

Unit I: Principles and elements of landscaping: Basic drawing skills, use of drawing instruments garden symbols, steps in preparation of garden design, programmes phase, design, phase, etc.

Elements and principles of landscape design. Organization of spaces, visual aspects of plan arrangement- view, vista and axis. Principles of circulation, site analysis and landscape, water requirement, use of recycled water.

Unit II: Landscaping for different situations: Urban landscaping, Landscaping for specific situations such as residential, farm houses, institutions, corporate sector, industries, hospitals, roadsides, traffic islands, Children parks, public parks, Xeriscaping, airports, railway station and tracks, river banks and dam sites and IT/ SEZ parks. Bio-aesthetic planning, eco-tourism, theme parks, indoor gardening, therapeutic gardening.

Practical

- Graphic language and symbols in landscaping, study of drawing instruments, viz., ‘T’ square, setsquare, drawing board, etc. (1);
- Identification of various types of ornamental plants for different gardens and occasions (1);
- Preparation of land, planning, layout and planting, deviations from landscapeprinciples (1);
- Case study (1);
- Site analysis, interpretation of map of different sites, use of GIS for selection (1);
- Enlargement from blue print. Landscape design layout and drafting on paper as per the scale (2);
- Preparation of garden models for home gardens, farm houses, industrial gardens, institutional gardens, corporate, avenue planting, practices in planning and planting of special types of gardens.(3);
- Burlapping, lawn making, planting of edges, hedges, topiary, herbaceous and shrubbery borders (2);
- Project preparation on landscaping for different situations, creation of formal and informal gardens (2);
- Visit to parks and botanical gardens (2).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training on different models of landscaping
- Exposure visits

Learning outcome

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

- The students will be apprised of different types of gardens and have a thoroughunderstanding of principles of landscape gardening
- Develop skills for landscaping under different situations and layout of gardencomponents.

Suggested Reading

- Bose TK, Chowdhury B and Sharma SP. 2011. *Tropical Garden Plants in Colour*. Hort. and Allied Publ.
- Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.
- Grewal HS and Singh P. 2014. *Landscape Designing and Ornamental Plants*. Kalyani Publishers, New Delhi.
- Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices.* Agrobios Publ., Jodhpur.
- Misra RL and Misra S. 2012. *Landscape Gardening*. Westville Publ. House, New Delhi, India. Nambisan KMP. 1992. *Design Elements of Landscape Gardening*. Oxford & IBH Publ. Co., New Delhi, India.
- Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.
- Sabina GT and Peter KV. 2008. *Ornamental Plants for Gardens*. New India Publ. Agency, New Delhi, India.
- Singh A and Dhaduk BK. 2015. *A Colour Handbook: Landscape Gardening*. New India Publ. Agency, New Delhi, India.
- Valsalakumari PK, Rajeevan PK, Sudhadevi PK and Geetha CK. 2008. *Flowering Trees*. New India Publ. Agency, New Delhi, India.
- Woodrow MG.1999. *Gardening in India*. Biotech Books, New Delhi, India.

Course Code : **FLS 506**

Course Title : **Indoor Plants and Interiorscaping**

Credit Hours : **(1+1)**

Why this course?

Indoor plants are an important component of floriculture. They not only improve the aesthetic environment of indoors but are also known to improve indoor air quality. The students in floriculture need up to date knowledge on factors affecting indoor growing, types, cultural operations and different principles of interiorscaping.

Aim of the course

To facilitate deeper understanding of the benefits of indoor plants, selection, designing and their management.

The course is organized as follows

No	Blocks	Units
1	Scope, principles and operations	I. Importance and scope II. Classification and principles III. Cultural operations
2	Presentations and marketing	I. Special gardens II. Vertical gardens III. Marketing

Theory

Block 1: Scope, principles and operations

Unit I: Importance and scope: Importance and scope of indoor plants and Interiorscaping, Indoor plants and Indoor air quality.

Unit II: Classification and principles: Factors affecting growth, development and flowering of Indoor plants. Classification of indoor plants based on light, temperature, humidity and pollution tolerance, Description and cultivation of various indoor plants. Principles of Interiorscaping, Role in pollution mitigation.

Unit III: Cultural operations: Containers and substrates, preparation of growing media, propagation, training, grooming, nutrition, management of disease, pests and weeds. Maintenance of plants including repotting, foliar nutrition, light exposure and plant rotation. Media standards, Nursery and Export standards for potted plants, Nursery standards.

Block 2: Presentations and marketing

Unit I: Special gardens: Special gardens including miniature gardens and plant stand. Presentations like dish, terrarium, bottle gardens, hanging baskets, window boxes and Bonsai.

Unit II: Vertical gardens: Vertical gardens- History, planting material, structures, containers, substrate, water and nutrient management, supplemental lighting.

Unit III: Marketing: Marketing channels, Business models including plant rentals.

Practical

- Identification of important house plants (2);
- Media and containers (1);

- Propagation (1);
- Cultural operations, maintenance and economics of indoor plants (2);
- Models for Interiorscaping (2);
- Familiarization with different indoor gardens (2);
- Making of terrariums, bottle garden, dish garden and their economics (2);
- Making of vertical gardens and economics (2);
- Exposure visits (2).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course, the students are expected to develop

- Deep understanding and knowledge of principles affecting indoor cultivationincluding vertical gardens
- Develop required skills in interiorscaping
- Develop required entrepreneurial acumen

Suggested Reading

- Barbara P. 2005. *The Complete Houseplant Survival Manual*. Storey Publ., New Adams. Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.
- Wallach C. 1995. *Interior Decorating with Plants*. McMillan Seed Production Co. Inc., New York.

Course Code : **FLS 507**

Course Title : **Nursery Management in Ornamental Plants**

Credit Hours : **(2+1)**

Why this course?

Nursery management is very essential for production of quality planting material in ornamental plants. The course gives a thorough understanding of propagation of different ornamental plants, nursery management, standards, law and certification.

Aim of the course

Familiarization with principles and practices of propagation and nursery management for Ornamental plants.

The course is organized as follows:

No	Blocks	Units
1	Nursery Industry and Propagation	I Scenario of nursery industry and sexualpropagation
		II Asexual propagation
		III Micropropgation
2	Nursery Management	I Growing structures
		II Sanitary and phytosanitary issues
		III Standards

Theory

Block 1: Nursery Industry and Propagation

Unit I: Scenario of nursery industry and sexual propagation: Importance and present scenario and status of nursery industry in India and in the world, life cycles in plants, Propagation methods, Factors influencing seed germination of flower crops, dormancy, seed quality, packing, storage, certification, testing. Hormonal regulation of germination and seedling growth.

Unit II: Asexual propagation: Methods of asexual propagation, rooting of soft and hard wood cutting under mist. Role of Plant growth regulators. Physiological, anatomical and biochemical aspects of root induction in cuttings. Layering – principles and methods, budding and grafting – selection of elite mother plants. Stock, scion and inter stock, relationship – Incompatibility.

Unit III: Micropropagation: Micro-propagation – principles and concepts, commercial eXploitation in flower crops. Techniques – *in-vitro* clonal propagation, direct organogenesis, embryogenesis, micrografting, meristem culture. Hardening, packing and transport of micro-propagules.

Block 2: Nursery Management

Unit I: Growing structures: Growing structures like mist chambers, tunnels, lath house, net house, growing media types, soil less culture and containers. Automation in nursery management.

Unit II: Sanitary and phyto-sanitary issues: Nursery – types, components, planning and layout. Nursery management practices for healthy propagule production. Nursery Act, PPV&FR act and Quarantine system in India. Important quarantine pests and diseases, sanitary and phyto-sanitary issues threats to nursery Industry.

Unit III: Standards: Nursery standards, Hi-tech nurseries, garden centers.

Practical

- Anatomical studies in rooting of cutting and graft union (2);
- Identification and production of plug plants, seedlings and saplings (2);
- Preparation of growing media and use of PGRs (2);
- Practice of propagation through specialized structures cuttings, layering, buddingand grafting (2);
- Preparation of growing media – testing of physical chemical composition like pH, EC
- Case studies (2);
- Micropropagation of ornamental crops and hardening (3);
- Visit to tissue culture labs and nurseries (2);
- Economics (1).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course,

- The students will develop thorough understanding of nursery management in flowercrops.
- Empower the students with the knowledge to start an enterprise
- Hone adequate skill in propagation and management

Suggested Reading

- Adriance GW and Brison FR. 2000. *Propagation of Horticultural Plants*. Biotech Books, NewDelhi, India.
- Bose TK, Mitra SK and Sadhu M K. 1991. *Propagation of Tropical and Subtropical HorticulturalCrops*. Naya Prokash, Kolkata, India.
- Chadha KL, Ravindran PL and Leela Sahijram. 2000. *Biotechnology in Horticulture andPlantation Crops*. Malhotra Publ. House, New Delhi, India.
- Davies Fred T Jr., Geneve RL, Wilson SB, Hartmann HT and Kester DL. 2018. *Hartmann and Kester's Plant Propagation: Principles and Practices.*

Pearson Publ. 9th Edition.

- Peter KV. 2008. *Basics of Horticulture*. New India Publ. Agency, New Delhi, India.
- Rajan S and Baby LM. 2007. *Propagation of Horticultural Crops*. New India Publ. Agency, New Delhi, India. pp. 251.
- Singh SP. 1989. *Mist Propagation*. Metropolitan Book Co., New Delhi, India.

Course Code : FLS 508

Course Title : Turfgrass Management
Credit Hours : (2+1)

Why this course?

Turf grass management deals with establishment and maintenance of different turf grasses for aesthetic, recreational and sports purposes. The course deals with basic types, requirement of turf grasses, management and development of turf for different purposes.

Aim of the course

To understand the science, principles and management of turf grasses.

The course is organized as follows:

No	Blocks	Units
1	Turf Industry and turf management requirement	I Prospects and basic requirement
		II Types of turf grasses
		III Operations and management
2	Turf for different ground	I Making of different sports arenas
		II Automation in turf management

Theory

Block 1: Turf industry and turf grasses

Unit I: Prospects and basic requirement: History, present status and prospects of turf industry; basic requirements, site selection and evaluation, concepts of quality of soil pertaining to turf grass establishment, criteria for evaluation of turf quality.

Unit II: Types of turf grasses: Types, species, varieties, important breeders, grasses for different locations and conditions and their compatible groupings as per climatic conditions; Turfing for roof gardens.

Unit III: Operations and management: Preparatory operations; Turf establishment methods such as seeding, sprigging/ dibbling, plugging, sodding/

turfing, turf plastering, instant turfing (portable), hydro- seeding, synthetic turfing. Turf management – Irrigation, drainage, nutrition, special practices like aerating, rolling, coring, dethatching, verticutting, soil top dressing, use of plant growth regulators and micronutrients, Turf mowing – mowing equipments, techniques to minimize wear and compaction, weed control, biotic and abiotic stress management in turfs, standards for turf, use of recycled water, etc.

Block 2: Turf for different grounds

Unit I: Making of different sports arenas: Establishment and maintenance of turfs for playgrounds, viz., golf, football, hockey, cricket, tennis, rugby, residential and public parks, turfing of Govt. and Corporate office gardens, event specific preparation, turf colourants.

Unit II: Automation : Exposure to different tools, gadgets, machinery used in turf industry.

Practical

- Identification of turf grasses and turf machinery (1);
- Soil preparation, turf establishment methods, provision of drainage (2);
- Layout of macro and micro irrigation systems (1);
- Water and nutrient management (2);
- Special practices – mowing, raking, rolling, soil top dressing, weed management(2);
- Biotic and abiotic stress management (2);
- Project preparation for turf establishment (2);
- Visit to parks, model cricket grounds and golf courses, airports, corporates, Govt.organizations (2);
- Rejuvenation of lawns (1);
- Turf economics (1).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

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

- Deep understanding and knowledge of different types of grasses and their management
- Developing skills for turfing of different arenas
- Develop required entrepreneurial acumen

Suggested Reading

- Aldous D.1999. *International Turf Management Handbook.* CRC Press. pp.368. Beard JB. 1972. *Turf Grass Science and Culture*. Pearson. 1st edition, pp. 672.
- Chawla SL, Patil S, Patel MA, Patel RB and Patel RM. 2013. *Turf grass Management*. Published by NAU, Navsari.
- Emmons R. 2007. *Turf grass Science and Management*. Cengage Learning Publ. 4th edition, pp.592.
- Nick-Christians. 2011. *Fundamentals of Turf grass Management*. Wiley; 4th Edition, pp. 424. Turgeon AJ. 1980. *Turf grass Management*. Reston Publ. Inc.

Course Code : FLS 509
Course Title : Value Addition in Floriculture
Credit Hours : (2+1)

Why this course?

Value addition is done to increase the economic value of any floriculture commodity. Students need to develop thorough understanding of scope, scenario and different methods of value addition so that they can improve the income of the stakeholders by value addition.

Aim of the course

To understand the avenues for value addition in floriculture

The course is organized as follows:

No	Blocks	Units
1	Value added products	I Scope and scenario II Value addition of loose flowers III Floral Arrangements IV Dry flowers
2	Extraction of value added products	I Essential oils II Pigments and nutraceuticals

Theory

Block 1: Value added products

Unit I: Scope and scenario: Scope and prospects of value addition, National and global scenario, production and exports. Types of value added products, techniques of value addition including tinting.

Unit II: Value addition in loose flowers: Value addition in loose flowers and product development- edible products like – Floral tea, floral wine, floral sherbet, floral ice creams, floral jelly, sweets, gulkhand, rose oil, rose water, Pankhuri, floral dyes, etc. non-edible products like incense sticks & organic gulal.

Unit III: Floral Arrangements: Selection of containers and accessories for floral products and decorations. Flower arrangement, styles, ikebana schools (*ikenobo, ohara, sogetsu,* etc.), Ikebana- moribana, nagiere, contemporary style.

Unit IV: Dry flowers: Dry flowers– Identification and selection of flowers and plant parts; Raw material procurement, preservation and storage; tips for collecting dry flower making, selection of stages for picking of flowers for drying, Techniques in dry flower making – Drying, glycerising, bleaching, dyeing, embedding, pressing; Accessories; Designing and arrangement – dry flower baskets,bouquets, pot-pourri, wall hangings, button holes, greeting cards, wreaths; petal embedded handmade papers, Packaging and storage. Post drying managementincluding moisture, pests and molds.

Block 2: Extraction of value added products

Unit I: Essential oils: Essential oils; Selection of species and varieties (including non-conventional species), extraction methods, Packing and storage, Aromatherapy.

Unit II: Pigments and nutraceuticals: Types of pigments, carotenoids, anthocyanins, chlorophyll, betalains; Significance of natural pigments as nutraceuticals, Extraction methods and applications in food, pharmaceutical and poultry industries.

Unit III: Dying: Synthetic and Natural dyes, dying techniques, colour retention,

Practical

- Practices in preparation of different type of flower arrangements including bouquets, button-holes, flower baskets, corsages, floral wreaths, garlands with fresh flowers (4);
- Techniques in flower arrangement and floral decoration (2);
- Identification of plants for dry flower making (2);
- Practices in dry flower making; Preparation of dry flower baskets, bouquets, pot-pourri, wall hangings, button holes, greeting cards, wreaths, etc. (2);
- Essential oil extraction units (1);
- Preparation of various edible and non-edible products from flowers((1)
- Extraction of pigments (2);

- Visit to dry flower units (1);
- Economics of value added products (1).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

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

- Understand and prepare different value added products from flowers
- Develop entrepreneurial acumen
- Imbibe the skills for making various value added products

Suggested Reading

- Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.
- Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants.* Vol.XII, Parts 1 & 2. pp.533 and pp.574. Malhotra Publ. House, New Delhi, India.
- Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices.*Agrobios Publ.,Jodhpur.
- Nowak J and Rudnicki RM. 1990. *Postharvest handling and storage of cut flowers, florist greens, and potted plants*. Timber Press, USA. pp. 210.
- Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publ., Jodhpur.
- Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India.

Course Code : FLS 510

Course Title : Protected Cultivation of Flower Crops

Credit Hours : (2+1)

Why this course ?

Protected cultivation is more rewarding in production of high value cut flowers. With appropriate structures and plant environment control measures, the constraints of environment prevalent in the region can be overcome allowing almost year- round cultivation. The students need a thorough understanding of principles, types, designs, crops for different environments and management of environment in protected cultivation.

Aim of the course

Understanding the principles, theoretical aspects and developing skills in protected cultivation of flower crops.

The course is organized as follows

No	Blocks	Units
1	Principles and types	I Prospects and types of protected structures
		II Principles and designs
2	Growing Environment	I Control of environment
		II Crop management and crop regulation
		III Automation and standards

Theory

Block 1: Principles and types

Unit I: Prospects and types of protected structures: Prospects of protected floriculture in India; Types of protected structures – Glasshouse/ polyhouse, shadenet houses, mist chambers, lath houses, orchidarium,fernery, rain shelters, etc.

Unit II: Principles and designs: Principles of designing and erection of protected structures; Low cost/ Medium cost/ High cost structures; Location specific designs; Structural components; Suitable flower and foliage plants for protected cultivation.

Block 2: Growing environment

Unit I: Control of environment: Microclimate management and manipulation of temperature, light, humidity, air and CO2; Heating and cooling systems,ventilation, naturally ventilated greenhouses, fan and pad cooled greenhouses, light regulation, water harvesting.

Unit II: Crop management and crop regulation: Containers and substrates, media, soil decontamination, layout of drip and fertigation system, water and nutrient management, IPM and IDM, Crop regulation by chemical methods and special horticultural practices (pinching, disbudding, deshooting, deblossoming, etc.); Staking and netting, Photoperiod regulation.

Unit III: Automation and standards: Automation in greenhouses, sensors, solar greenhouses and retractable greenhouses, GAP/ Flower labels, Export standards, EXIM policy, APEDA regulations export, Non-tariff forbarriers.

Crops

Rose, Chrysanthemum, Carnation, Gerbera, Orchids, Anthuriums, Lilium,Limonium, Lisianthus, heliconia, Cala lily, Alstromeria, etc.

Practical

- Study of various protected structures (1);
- Design, layout and erection of different types of structures (2);
- Practices in preparatory operations, growing media, soil decontamination techniques (2);
- Microclimate management (2);
- Practices in drip and fertigation techniques, special horticultural practices (2);
- Determination of harvest indices and harvesting methods (1);
- Postharvest handling, packing methods (1);
- Economics of cultivation, Project preparation (2);
- Project Financing guidelines (1);
- Visit to commercial greenhouses (2).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

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

- Knowledge on types, design and principles of protected structures
- Thorough understanding of principles of microclimate management and crop management.
- Develop the required skills for designing a greenhouse
- Acquire skills on microclimate management, production management

Suggested Reading

- Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.
- Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.

- Bose TK and Yadav LP. 1989. *Commercial Flowers*. Naya Prokash, Kolkata, India.
- Chadha KL and Bhattacharjee SK. 1995. *Advances in Horticulture: Ornamental Plants*. Vol.XII, Parts 1 & 2. pp.533 and pp.574. Malhotra Publ. House, New Delhi, India.
- Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices.*Agrobios Publ.,Jodhpur.
- Nelson PV. 2011. *Green House Operation and Management*. Pearson Publ. 7th edition, pp. 624. Prasad S and Kumar U. 2003. *Commercial Floriculture*. Agrobios Publ., Jodhpur.
- Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.
- Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India

Course Code : FLS 511
Course Title : CAD for Landscaping
Credit Hours : (1+2)

Why this course ?

CAD is widely used in landscaping planning and design. The students need to develop in depth knowledge of CAD software so that they can modify raw data into plans, drawing and models for landscape planning.

Aim of the course

To impart basic knowledge about the Computer Aided Designing (CAD) of landscape.

The course is organized as follows

No	Blocks	Units
1	AUTOCAD	I CAD basics and applications II 2D drawing
2	Sketch Up	I 3D modelling II Visualization

Theory

Block 1: AUTOCAD

Unit II: CAD basics and applications: Principles of integrating the architectureand landscaping, Exposure to CAD (Computer Aided Designing) – Applications of CAD in landscape garden designing, 2D drawing by AUTOCAD, Creating legendsfor plant and non-plant components, Basics of Photoshop software in garden designing.

Unit II: 2D drawing: 2D drawing methods, AUTOCAD Basics, Coordinate systems in AUTOCAD, Point picking methods, Toolbars and Icons, File handling functions, Modifying tools, Modifying comments, Isometric drawings, Drafting objects. Using patterns in AUTOCAD drawing, Dimension concepts, Hyperlinking, Script making, Using productivity tools, e-transmit file, makingsample drawing for outdoor and indoor garden by AUTOCAD 2D Drawing techniques, Making layout.

Block 2: Sketch up

Unit I: 3D modelling**:** Basics of 3d Modelling, Modellig Tools, Modifier Tools, NavigationTools, Sections, Material Application, Creating Components And Groups, Sketch Up Styles, Importing Files To Sketch Up, Exporting Files To Other Software, Plug-Ins, Geo-Location, Sandbox Tools, Creating Scenes, ExportingImages, Dimensioning And Labeling.

Unit II: Visualisation**:** Basic Introduction To Archicad, Rhino, Revit, Lumion; Use Of Sketchup 3D Warehouse, Introduction To Photoshop, Visualization Techniques Using Sketch Up And Other External Applications Like Photoshop And Lumion.

Practical

- AutoCAD: use of drawing tools, modifier tools, layers, blocks, dimensioning, text,labelling, plotting drawings
- Drawing designs for home harden, small park, hospitality/ institutional landscapes ,theme parks, interior scaping (increasing plot size and complexity)
- Basics of AutoCAD 3D and introduction to Sketch Up
- Sketch Up: using drawing and modifier tools to draw basic shapes.
- Advanced 3D modelling to draw different gardens of increasing size and complexity
- Basics of Layout in Sketch Up
- Exploring visualization techniques using Sketch Up
- Photoshop: introduction and basic image manipulation to aid in visualization
- Exposure visits (4).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes

- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course, the students are expected to develop

- The students will be able to use CAD and ARCHICAD for landscape planning anddesigning.
- Develop the adequate skills to create 3 D model to showcase interaction of differentfactors in landscape gardening.
- Develop the entrepreneurial acumen

Suggested Reading

- Christine, Wein-Ping Yu. 1987. *Computer-aided Design: Application to Conceptual Thinkingin Landscape Architecture*. amazon.com.
- Misra RL and Misra S. 2012. *Landscape Gardening*. Westville Publ. House, New Delhi, India.

Course Code : **FLS: 512**

Course Title : **Seed Production in Flower Crops**

Credit Hours : **(1+1)**

Why this course ?

Seed production of flowers is a highly remunerative enterprise. The students need to have knowledge of seed industry, seed production methods and seed certification. This course provides hands on training on seed production of important flower crops.

Aim of the course

To impart basic knowledge about the importance of seed production in important flower crops.

The course is organized as follows

No	Blocks	Units
1	Seed Industry	I Scenario of Seed industry
2	Hybrid Seed Production	I Seed Production methods II Population improvement III F1 Hybrid production

Theory

Block 1: Seed Industry

Unit I: Scenario of Seed Industry: Scope, scenario and importance of seed production in flower crops. Constraints in flower seed production. Marketing and economics of flower seeds.

Block 2: Hybrid Seed Production

Unit I: Seed production-Methods: Methods of seed production, agrotechniques for production of nucleus, breeder and certified seeds. Harvesting, seed processing, seed priming, seed chain, packaging and storage.

Unit II: Population improvement: Mass selection, progeny selection. Use of incompatibility and male sterility, maintenance of variety and seed production in flower crops.

Unit III: F1 hybrid production: F1 hybrid seed production advantages, steps involved in hybrid seed production, pollination behaviour and isolation, pollination management methods in production of F1/ hybrids in different flower crops.

Block 3: Regulations

Unit I: Seed certification and standards: Seed certification, Seed standards, seed act, plant breeders rights and farmers' rights, Bio safety, handling of transgenic seed crops, importing of seeds and OGL, trade barriers in seed business, sanitary and phytosanitaty issues, custom clearance and quarantine.

Crops

Marigold, balsam, china aster, celosia, petunia, antirrhinum, zinnia, pansy, lupin, calendula, phloX, vinca, dianthus, sunflower, annual chrysanthemum, poppy, cornflower, rice flower.

Practical

- Seed production of open pollinated varieties (2);
- Seed production of cross pollinated varieties (2);
- Steps involved in hybrid seed production (2);
- Hybrid seed production in different flower crops like marigold, petunia, antirrhinum, zinnia, pansy, lupin, calendula, phlox, vinca, dianthus, sunflower, annual chrysanthemum, etc. (6);
- Visit to seed industry (3);
- Visit to quarantine facility (1).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course,

- The students will get a thorough knowledge on seed industry, principles andmethods of seed production in flower crops.
- Students will get awareness on seed standards, certification and law in flowercrops.

Suggested Reading

- Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, pp. 2065.
- Bose TK, Yadav LP, Pal P, Parthasarathy VA and Das,P. 2003. *Commercial Flowers*. Vol. I & II. Naya Udyog, Kolkata, India.
- Davies, Fred T Jr., Geneve RL, Wilson SB, Hartmann HT. Kester DL. 2018. *Hartmann and Kester's Plant Propagation: Principles and Practices.* Pearson Publ.9th Edition.
- Larson RA and Armitage AM. 1992. *Introduction of Floriculture*. International Book DistributingCo., Lucknow, India.

Course Title with Credit Load for Ph.D (Hort) in Floriculture and Landscaping

Course Code	Course Title	Credit Hours
	Major Courses(12 Credits)	
FLS 601*	Crop Regulation in Ornamental Crops	2+1
FLS 602*	Postharvest Biology of Floricultural Crops	2+1
FLS 603	Specialty Flowers, Fillers and Cut Greens	1+1
FLS 604	Biotechnological Approaches in Floricultural Crops	2+1
FLS 605*	Advances in Landscape Gardening	1+2
FLS 606	Vertical Gardening	1+2
FLS 607	Modern Approaches in Breeding of Floricultural crops	2+1
FLS 608	Advances in Production Technology of Flower Crops	2+1
FLS 609	Advances in Protected Cultivation of Flower Crops	2+1
	Minor courses	06
	Supporting courses	05
FLS 691	Doctoral Seminar-I	0+1
FLS 692	Doctoral Seminar-II	0+1
FLS 699	Doctoral Research*	0+75
	Total Credits	**100**

*Compulsory among major courses

Course Code : FLS 601
Course Title : Crop Regulation in Ornamental Crops
Credit Hours : (2+1)

Why this course ?

The course deals with the physiological and biochemical basis of crop regulation and programmed production of flower crops. The students need a thorough understanding on crop regulation to improve the profitability of growers.

Aim of the course

Appraise on advances in programmed production of flower crops

The course is organized as follows:

No	Blocks	Units
1	Basis of crop regulation	I Basis of flowering II Growth regulators
2	Programming	I Growth regulation II Programmed production

Theory

Block 1: Basis of crop regulation

Unit I: Basis of flowering: Ecophysiological influences on growth development of flower crops for flowering, Crop load and assimilate partitioning and distribution. Root and canopy regulation.

Unit II: Growth regulators: Study of plant growth regulators including biostimulants and polyamines in floriculture- structure, biosynthesis, metabolic and morphogenetic effects of different plant growth promoters and growth retardants. Absorption, translocation and degradation of phytohormones – internal and external factors influencing hormonal synthesis, biochemical action, growth promotion andinhibition, Plant architecture management for flower crops and ornamental plants, molecular approaches in crop growth regulation.

Block 2: Programming

Unit I: Growth regulation: Growth regulation aspects of propagation, embryogenesis, seed and bud dormancy, flower bud initiation, regulation of flowering, photo and thermo periodism, off season production, bulb forcing techniques.

Unit II: Programmed production: Programmed production of important flower crops like chrysanthemum, tulips, lilium, daffodils, poinsettia, kalanchoe, gypsophila.

Practical

- Plant architecture studies in important flower crops (2);
- Bioassay and isolation through chromatographic analysis for auxins, gibberellins,cytokinins, ABA (4);
- Growth regulation during propagation, dormancy, flowering (2);
- Photoperiod regulation in short day and long day crops (2);
- Off season production in important crops (2);
- Bulb forcing in bulbous ornamental crops (2);
- Exposure visits (2).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course,

- The students will be abreast with physiological and biochemical basis of cropregulation in flower crops.
- The students will be able to carry out programmed production of flower crops.
- Instill the entrepreneurial acumen in the students

Suggested Reading

- Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. 2015. Wiley Blackwell Publ. 2nd Edition, pp. 1280.
- De Hertagh A and Le Nard M. 1993. *The Physiology of Flower Bulbs*. Elsevier, London, UK. Epstein E. 1972. *Mineral Nutrition of Plants: Principles and Perspectives*. John Wiley & Sons. Fosket DE. 1994. *Plant Growth and Development: A Molecular Approach*. Academic Press. pp.580.
- Leoplod AC and Kriedermann PE. 1985. *Plant Growth and Development*. McGraw-Hill, NewYork. 3rd Edition.
- Peter KV. 2008. *Basics of Horticulture*. New India Publ. Agency, New Delhi, India.
- Roberts J, Downs S and Parker P. 2002. *Plant Growth Development*: *In Plant.* OXford UniversityPress. pp. 221-274.
- Salisbury FB. and Ross CW. 1992. *Plant Physiology, Hormones and Plant Regulators: Auxins and Gibberellins.* Wadsworth Publ., Belmont. 4th Edition, pp. 357-381.

Course Code : **FLS 602**
Course Title : **Postharvest Biology of Floricultural Crops**
Credit Hours : **(2+1)**

Why this course ?

The course deals with physiological, biochemical basis of senescence of flowers and the treatments and packaging methods to mitigate these processes for improving post-harvest life.

Aim of the course

To facilitate deeper understanding of biochemistry and postharvest technology in flowers at molecular as well as applied level.

The course is organized as follows:

No	Blocks	Units
1	Pre-harvest and post harvest physiology and biochemistry	I Pre harvest physiology
		II Senescence
		III Pigments and secondary metabolites
2	Storage and packaging	I Treatments and storage
		II Packaging
		III Recent Trends
		IV Dried ornamental crops

Theory

Block 1: Preharvest and post harvest physiology and biochemistry

Unit I: Pre harvest physiology: Maturity indices, harvesting practices for specific market requirements, influence of pre-harvest practices, enzymatic and other biochemical changes, respiration, transpirationin important flower crops.

Unit II: Senescence: Physiology and biochemistry of flowering, enzymatic changes, Ethylene sensitivity, ethylene evolution and management, factors leading to post-harvest loss, pre-cooling. Petal senescence at molecular level, functional gene analysis for postharvest flower quality in important flower crops, etc.

Unit III: Pigments and secondary metabolites: Biosynthetic pathways of chlorophyll, Xanthophyll, carotenoids, flavonoids and anthocyanins and betalains. Chemistry and importance of secondary metabolites. Biochemistry and utilization for commercial products in important flower crops.

Block 2: Storage and packaging

Unit I: Storage of flowers: Treatments prior to shipment, viz., precooling, pulsing, impregnation, chemicals, Irradiation, biocontrol agents and natural plant products. Methods of storage: ventilated, refrigerated, Modified atmosphere, Controlled atmosphere storage, cool chain management, physical injuries and disorders in important flower crops.

Unit II: Packaging: Packing methods and transport, Smart technologies in packaging and storage, advanced tools like nanotechnology application for quality parameters and post harvest treatments for export in important flower crops, packaging standards, flower labels value chainin floriculture.

Unit III: Recent trends: Recent trends- extraction of bio-colours from flowers-conventional as well as *in-vitro* methods and their value addition uses in food and textile industries. Molecular techniques for enhancing postharvest flower quality, transgenics in ornamental plants forenhanced postharvest life.

Unit IV: Dried ornamental crops: Post harvest handling of dried ornamental crops including packing, storage and shipment. Storage pest and mould problems in dried ornamental produce, colour retention, physiological and biochemical changes, etc.

Practical

- Improved packaging and storage of important flowers (2);
- Physiological loss in weight of flowers, estimation of transpiration, respirationrate, ethylene release and study of vase life (2);
- Extension in cut flower vase life using chemicals (1);
- Estimation of quality characteristics in stored flowers (1);
- Estimation of biochemical changes like enzymatic changes, lipids and electrolyteleakage (2);
- Extraction of flower pigments – Chlorophyll, Xanthophylls, carotenoids and anthocyanins (4);
- Cold chain management – visit to cold storage, MA and CA storage units (2);
- Project preparation (2).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course,

- The students will be abreast with physiological and biochemical basis of senescencein flower crops.
- The students would acquire the required skill sets of managing the storage andpackaging methods to be followed in case of flowers.
- Prepare the students to explore the entrepreneurial options in post harvest management.

Suggested Reading

- Buchanan B, Gruiessam W and Jones R. 2002. *Biochemistry and Molecular Biology of Plants*. 2015. Wiley Blackwell Publ. 2nd edition, pp. 1280.
- Dey PM and Harborne JB. 1997. *Plant Biochemistry*. Academic Press. 2nd Edition.
- Glover MD. 1984. *Gene Cloning: The Mechanics of DNA Manipulation*. Chapman & Hall Publ. Goodwin TW and Mercer EI. 2003. *Introduction to Plant Biochemistry*. CBS Publ.

Course Code : FLS 603
Course Title : Specialty Flowers, Fillers and Cut Greens
Credit Hours : (1+1)

Why this course ?

This course deals with introduction to specialty flowers, cut greens and fillers, ways to cultivate them and their post harvest handling and storage. The students need to be aware of these crops so that they could improve the profitability of growers.

Aim of the course

To impart the knowledge on importance and cultivation of specialty flowers, fillers and cut green crops.

The course is organized as follows:

No	Blocks	Units
1	Scope	I Importance, national and international scenario
2	Avenues	I Specialty flowers II Fillers III Cut greens
3	Trade and marketing	I Post harvest management and marketing II Standards

Theory

Block 1: Scope

Unit I: Importance, national and international scenario: Introduction, present status, scope, importance and avenues for specialty flowers and cut greens.

Block 2: Avenues

Unit I: Specialty flowers: Cultivation practices of specialty flower crops like heliconia, red ginger, Bird of Paradise, Ornamental banana, ornamental curcuma, gingers, wax flower, kangaroo paw, limonium, rice flower, etc.

Unit II: Fillers: Cultivation practices of fillers like gypsophila, solidago, Mollucella, lupins, etc.

Unit III: Cut greens: Cultivation practices of cut greens like anthurium, ferns, asparagus, cycas, thuja, bottle brush, ornamental palms, philoendrons, dracaena, eucalyptus, ruscus, dianella, alpinia, etc.

Block 3: Trade and Marketing

Unit I: Post harvest management: Pre and post harvest factors influencing the vase life of the flowers and fillers, Post harvest management including pulsing, holding, packing, storing, forward and backward linkages, value chain management.

Unit II: Standards: Quality standards, Packaging standards, marketing and trade in important flower, filler and foliage crops.

Practical

- Identification of specialty flowers, fillers and cut greens (2);
- Media and bed preparation for cultivation (2);
- Propagation of important crops (2);
- Integrated disease and pest management in important crops (2);
- Post harvest handling of specialty flowers, fillers and cut greens (2);
- Preparation of value added products from important specialty flowers, fillers andfoliage (2);
- Exposure visits (2);
- Economics and Project preparation (2).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course,

- The students will gain knowledge on different specialty flowers, cut greens, fillerstheir cultivation practices and post harvest management.
- Infuse confidence to take up cultivation as an enterprise.

Suggested Reading

- Armitage AM and Laushman JM. 2008. *Speciality Cut Flowers*. Timber Press. 2nd Edition, pp.636.
- Bhattacharjee SK. 2006. *Vistas in Floriculture*. Pointer Publ., Jaipur, India.
- Bhattacharjee SK and De LC. 2003. *Advanced Commercial Floriculture* Vol.1. Aavishkar Publ. & Distributors, Jaipur India.
- Bose TK, Yadav LP, Pal P, Parthasarathy VA and Das P. 2003. *Commercial Flowers*. Vol. I & II. Naya Udyog, Kolkata, India.
- Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Traditional and Loose Flowers*. Kruger Brentt Publisher UK Ltd.
- Mukherjee D. 2008. *Speciality Cut Flowers-Production Technologies*. Naya Udyog Kolkata, India. pp. 614.
- Salunkhe K, Bhatt NR and Desai BB. 2004. *Post harvest Biotechnology of Flowers and Ornamental Plants*. Naya Prokash, Kolkata, India.

Course Code : **FLS 604**
Course Title : **Biotechnological Approaches in Floricultural Crops**
Credit Hours : **(2+1)**

Why this course ?

This course deals with advances in biotechnology of flower crops. The student needs to be abreast with recent advances in tissue culture, genetic engineering and molecular biology of flower crops

Aim of the course

Equip the students with the advances in application of biotechnology in flower crops.

No	Blocks	Units
1	Scope of biotechnology	I Scope of biotechnology
2	Cell, Tissue and Organ culture	I Tissue cultures
		II Somaclonal variation and *in-vitro* conservation
3	Genetic engineering and molecular biology	I Genetic Engineering
		II Molecular approaches

Theory

Block 1: Scope of biotechnology

Unit I: Scope of biotechnology: Present status of biotechnology, tools techniques and role in floriculture industry, physical factors and chemical factors influencing thegrowth and development of plant cell, tissue and organs, cyto-differentiation, organogenesis, somatic embryogenesis in important flower crops.

Block 2: Cell, tissue and organ culture

Unit I: Tissue culture: *In-vitro* lines for biotic and abiotic stress – Meristemculture for disease elimination, production of haploids through anther and pollen culture – embryo and ovule culture, micrografting, wide hybridization and embryo rescue techniques, construction of somatic hybrids and cybrids, regeneration and characterization of hybrids andcybrids, *in-vitro* pollination and fertilization, hardening media, techniques and establishment of tissue culture plants in the primary and secondary nursery in important flower crops.

Unit II: Somaclonal variation and *in-vitro* conservation: Somoclonal variation and its applications – variability induction through *in-vitro* mutation, development of cell suspension cultures, types and techniques, Synthetic Seed technology, *in-vitro* production of secondary metabolites, role of bioreactors in production of secondary metabolites, quantification and quality analysis of secondary metabolites using HPLC/ MS/ GCMS/ *in-vitro* conservation and cryo-preservation techniques in important flower crops.

Block 3: Genetic engineering and molecular biology

Unit I: Genetic engineering: Gene cloning, genetic engineering: vectors and methods of transformation – electroporation, particle bombardment, Functional gene analysis techniques like PTGS including VIGS in ornamental plants, Agrobacterium mediated, transgenic plants in flower crops, Biosafety of transgenics isolation of DNA, RNA, quantification, Polymerase Chain Reaction for amplification; AGE and PAGE techniques; identification of molecular markers in important flower crops.

Unit II: Molecular approaches: Molecular markers as a tool for analysis of genetic relatedness and selection in ornamental crops. Molecular control of flower development, light sensing with respect to plant development, flower pigmentation, fragrance, senescence, ethylene synthesis pathway in important flower crops. Molecular biology-Gene isolation, characterization, manipulation and transfer in important flower crops.

Construction of c- DNA library, DNA fingerprinting technique in economic flower crop varieties, RNAi, Genome editing basics, molecular approaches to control ethylene response, Fragrance, Plant Architecture, desirable flower traits, colour, shape,improving postharvest life, improving resistance for environmental stress, approachesto improve flower development, pigment production, secondary metabolite production, post harvest biotechnology of flowers, ornamental plants, achievements of bio-technology in flower crops.

Practical

- Micropropagation, Pollen- Ovule and Embryo culture- Synthetic seed production (2);
- *In-vitro* mutation induction, *in-vitro* rooting – hardening at primary and secondary nurseries (3);
- DNA isolation from economic flower crop varieties – Quantification and amplification (2) DNA and Protein profiling – molecular markers, PCR Handling(2);
- Vectors for cloning and particle bombardment (3);
- DNA fingerprinting of flower crop varieties (3);
- Project preparation for establishment of low, medium and high cost tissue culturelaboratories (1).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Suggested Reading

- Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology-Concepts, Methods and Applications*. OXford & IBH Publ. Company, USA. pp. 200.
- Debnath M. 2011. *Tools and Techniques of Biotechnology*. Pointer Publ.
- Glover MD. 1984. *Gene Cloning: The Mechanics of DNA Manipulation*. Chapman & Hall Publ. Gorden H and Rubsell S. 1960. *Hormones and Cell Culture*. AB Book Publ.
- Keshavachandran R, Nazeem PA, Girija D, John PS and Peter KV. 2007. *Recent Trends in Horticultural Biotechnology*. Vols. I & II, 1018 p. New India Publ. Agency, New Delhi, India.
- Keshavachandran R and Peter KV. 2008. *Plant Biotechnology: Methods in Tissue Culture andGene Transfer*. Orient Blackswan. 312 p.

Course Code : **FLS 605**

Course Title : **Advances in Landscape Gardening**

Credit Hours : **(1+2)**

Why this course ?

Advances in landscape gardening is a course which deals with principles of landscape design, landscape engineering and site analysis. It will also create awareness on latest developments in landscape gardening among students.

Aim of the course

To update knowledge on the recent trends in the field of landscape designing and developing practical skills.

The course is organized as follows:

1. Landscape design
2. Site analysis
3. Software in landscaping
4. Landscaping for different situations
5. Maintenance

Theory

Unit I

Landscape design: Commercial landscape gardening- History, Plant identification and ecology, Materials of garden design, Design making by different garden styles and types. Design principles in ancient and modern landscape. Principles of designing a commercial landscape project. Role of landscaping in environment improvement, ecology conservation (birds, butterflies, animals). Plant wealth for edges, hedges, herbaceous borders, trees, floral beds, water plants, cacti, ferns, palms, etc.

Unit II

Site analysis: Assessing site and plants adaptability for different locations, Landscape engineering (Topographical survey and designing concept including GIS, GPS, Remote sensing), special techniques in garden landscaping (Burlapping, waterscaping, Xeriscaping, hardscaping, lawn establishment, topiary styles specializing bioaesthetic planning).

Unit III

Software in landscaping: Preparation and drawing of site plan, Learning the basics in computer aided design (CAD) for developing a garden landscape plan, Handling soft landscape materials (AUTOCAD and ARCHICAD), GIS as a tool for spatial designing.

Unit IV

Landscaping for different situations: Contemporary landscaping, Urban landscaping, Environmental landscaping, Industrial and institutional landscaping, Public and private garden making, play ground landscaping, Inventory management, Landscape restoration, Assessing a successful design in site.

Unit V

Maintenance: Maintenance of different types of gardens, waste water utilisation, historical and archaeological garden sites, Permissions required for bigger projects, carbon sequestration, carbon credits etc.

Practical

- Plant identification (1);
- Materials of garden design, Design making by different garden styles and types (2);
- Assessing site and plants adaptability for different locations (2);
- Way of designing a commercial landscape project (4);
- Landscape engineering (Topographical survey and designing concept) (2);
- Preparation and drawing of site plan (4);
- Learning the basics in computer aided design (CAD) for developing a garden landscape plan (4);
- Handling soft landscape materials (AUTOCAD and ARCHICAD), GIS as a toolfor spatial designing (4);
- Case study with the successful landscapist (4);
- Budget/ Project cost estimating (2);
- Exposure visits (3).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course,

- The students will be abreast with the recent advances in landscape gardening

- Acquire the skills to independently handle landscape projects

Suggested Reading

- Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.
- Nambisan KMP.1992. *Design Elements of Landscape Gardening*. Oxford & IBH Publ. Co., New Delhi, India.
- Ozayuvuz M. 2013. *Advances in Landscape Architecture*. In Tech Open Publ. Woodrow MG. 1999. *Gardening in India*. Biotech Books, New Delhi, India

Course Code : **FLS 606**

Course Title : **Vertical Gardening**

Credit Hours : **(1+2)**

Why this course ?

This course deals with development in vertical gardening which is expanding across the country. In view of the unprecedented pollution, advent of smart cities demand for green walls/ living walls is increasing day by day. The students therefore need to be equipped with the advancements taking place to offer solutions.

Aim of the course

Equip the students with the latest developments in vertical gardening.

No	Blocks	Units
1	Importance	I Scope II Growth III Making of vertical garden
2	Green roofing	I Green facades II Mitigation of pollution III Maintenance

Theory

Block 1: Importance

Unit I: Scope: Present status of vertical gardening, benefits of vertical gardening, History of vertical gardens, role of indoor plants inmitigating pollution.

Unit II: Growth: Factors influencing the growth and development of the plants including light, humidity, temperature, nutrition, irrigation, growth regulation.

Unit III: Making of vertical gardens: Containers, media, frames, cost effective components, cables, wires, nets for the vertical formations, modular living walls.

Block 2: Green roofing

Unit I: Green Facades: Influence of green facades in providing thermal comfort, atmospheric cleansing and related environmental benefits, Energy saving potential of green façades, Aesthetic appeal of green structures and other relevant studies on urban greening.

Unit II: Mitigation of pollution: Plants suitable, Dust mitigation, Radiation absorption, Pollution mitigation, Acoustic attributes of urban greening.

Unit III: Maintenance: Lifecycle, maintenance, Plants with low light, medium, high intensity requirement, cost effectiveness and overall sustainability of living walls.

Practical

- Identification of plants (2);
- Components of vertical gardens (2);
- Designing of vertical gardens for different locations (4);
- Maintenance of vertical gardens (2);
- Economics (1);
- Project preparation (1);
- Exposure visit (4).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Suggested Reading

- Chopra VL and Nasim A. 1990. *Genetic Engineering and Biotechnology-Concepts, Methods andApplications*. OXford & IBH Publ. Company, USA. pp. 200.
- Debnath M. 2011. *Tools and Techniques of Biotechnology*. Pointer Publ.
- Glover MD. 1984. *Gene Cloning: The Mechanics of DNA Manipulation*. Chapman & Hall Publ.Gorden H and Rubsell S. 1960. *Hormones and Cell Culture*. AB Book Publ.
- Keshavachandran R, Nazeem PA, Girija D, John PS and Peter KV. 2007. *Recent Trends in Horticultural Biotechnology*. Vols. I & II, pp. 1018. New India Publ. Agency, New Delhi, India.

- Keshavachandran R and Peter KV. 2008. *Plant Biotechnology: Methods in Tissue Culture and Gene Transfer*. Orient Blackswan. pp. 312

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Course Code : **FLS 607**
Course Title : **Modern Approaches in Breeding of Floricultural crops**
Credit Hours : **(2+1)**

Why this course ?

There have been several advances in application of biotechnology of flower crops. The students need to be aware of a wide array of *in-vitro* and molecular techniques with reference to flower crops.

Aim of the course

To teach students about the recent research trends in the field of breeding of ornamental crops with special emphasis on biotechnological approaches.

The course is organized as follows:

No	Blocks	Units
1	*In-vitro* techniques and biosynthetic pathways	I *In-vitro* techniques
		II Biosynthetic pathways
2	Molecular techniques	I Molecular breeding
		II Genome editing
		III. Advances in flower crops

Theory

Block 1: *In-vitro* techniques and biosynthetic pathways

Unit I: *In-vitro* techniques: Role of biotechnology in improvement of flower crops; *in-vitro* mutagenesis, embryo culture, somaclonal variation, transformation, *in- vitro* cryopreservation, somatic hybridization, anther and ovule culture including somatic embryogenesis.

Unit II: Biosynthetic pathways: Biosynthetic pathways of pigment, fragrance and senescence, flower form; chemistry and importance of secondary metabolites, genomics, proteomics, metabolomics.

Block 2: Molecular techniques

Unit I: Molecular breeding: Molecular breeding and Marker assisted selection; molecular characterization; construction of c-DNA library; High throughput sequencing.

Unit II: Genome editing: Genome editing, CRISPER CAS, gene pyramiding, allele mining.

Unit III: Advances in flower crops: Breeding for biotic and abiotic stresses using biotechnological means; designer flower crops. Advancements in important flower crops like rose, chrysanthemum, carnation, orchids, anthuriums, lilium, gerbera, etc.

Practical

- *In-vitro* mutagenesis, embryo culture, somaclonal variation (2);
- Somatic hybridization, anther and ovule culture and somatic embryogenesis (2)
- Genetic transformation (2);
- Genetic fingerprinting, Genome editing techniques (4);
- PCR, genomics, blotting techniques (2);
- Cloning, marker assisted selection (2);
- Bioinformatics (2).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course,

- The students will have in depth knowledge and hands on training in *in-vitro* andmolecular approaches that can be used in flower crops.
- Equip the students with the skills for develop designer crops

Suggested Reading

- Anderson NO. 2007. *Flower Breeding and Genetics Issues, Challenges and Opportunities for the 21st Century*. Springer Publ., The Netherlands.
- Arthur ML. 2013. *Introduction to Bioinformatics*. OXford University Press, U.K. 400 p. Chadha KL and Chaudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.
- Nelson DL and CoX MM. 2000. *Principles of Biochemistry*. 4th Edition, Lehninger Publ. Panopoulas NJ (Ed.). 1981. *Genetic Engineering in Plant Sciences*. Praeger Publ.
- Parthasarathy VA, Bose TK, Deka PC, Das P, Mitra SK and Mohanadas S. 2001. *Biotechnology of Horticultural Crops*. Vol. I-III. Naya Prokash, Kolkata, India.

- Pierik RLM. 1987. *In-vitro Culture of Higher Plants*. MartinusNijhoff Publ. Amsterdam. Primrose SB and Twyman R. 2006. *Principles of Gene manipulation and Genomics*. Blackwell Publ., USA.
- Srivastava PS, Narula A and Srivastava S. 2005. *Plant Biotechnology and Molecular Markers*. Anamaya Publ., New Delhi, India.
- Vainstein A. (Ed.) 2002. *Breeding for Ornamental crops: Classical and Molecular Approaches*. Springer-Science-Business Media, B.V. 1st Edition.
- Wilson K and Walker J. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*. 7th Edition, Cambridge University Press, UK.

Course Code : **FLS 608**

Course Title : **Advances in Production Technology of Flower Crops**

Credit Hours : **(2+1)**

Why this course ?

Production technology of flower crops is undergoing a rapid change due to advances from other sciences. The students need to keep abreast with these advances in production technology in flower crops.

Aim of the course

To keep abreast with latest developments and trends in production technology of flower crops.

The course is organized as follows:

No	Blocks	Units
1	Production technology	I Scope and scenario II Cultural operations III Crop regulation IV Advances in production technology
2	Mechanization and Post harvest management	I Mechanization II Post harvest management

Theory

Block 1: Production technology

Unit I: Scope and scenario: Commercial flower production; Scope and importance; Global Scenario in cut flower production and trade, varietal wealth anddiversity; Soil and Environment; cut flower, loose flowers, dry flowers and essential oil trade, flower seed production. Special characteristics and requirements. Essential oil industry, recent advances in extraction methods.

Unit II: Cultural operations: Propagation and multiplication; Greenhouse management;

Soil/ media decontamination techniques; Microirrigation; nutrition and fertigation; slow release fertilizers and biofertilizers; influence of environmental parameters, light, temperature, moisture, humidity and CO_2 on growth and flowering.

Unit III: Crop Regulation: Flower forcing and year-round flowering through physiological interventions; Chemical regulation; Environmental manipulation, important insect pests, diseases, nematodes and their management through IPM and IDM, quarantine measures for export and other export norms.

Unit IV: Advances in production technology of flower crops: Advances in roses, chrysanthemum, carnation, tuberose, gladiolus, lilum, gerbera, orchids, anthuriums, etc.

Block 2: Mechanization and Post harvest management

Unit I: Mechanization: Mechanization, automation, ICT and AI in floriculture.

Unit II: Post-harvest management: Harvest indices, Harvesting techniques; Post harvest handling for local, distant and export market, Cluster production, Contract farming, FPOs, Value chain management.

Practical

- Greenhouse management; Soil decontamination techniques (2);
- Microirrigation; Nutrition and fertigation (2);
- Special practices- bending, netting, pinching, disbudding, defoliation and chemicalpruning, etc. (2);
- Photoperiodic and chemical induction of flowering (2);
- Assessing harvest indices; Post-harvest handling (2);
- Case studies (2);
- Visit to commercial cut flower and essential oil units (4).

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course,

- The students will acquire knowledge and skills in advances in production technology, crop regulation and mechanization in flower crops.
- Develop enterprising attitude among students.

Suggested Reading

- Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.
- Chadha KL and Choudhury B. 1992. *Ornamental Horticulture in India*. ICAR, New Delhi, India.
- George S and Peter KV. 2008. *Plants in a Garden*. New India Publ. Agency, New Delhi, India. Lauria A and Victor HR. 2001. *Floriculture-Fundamentals and Practices.* Agrobios Publ., Jodhpur, India.
- Misra RL and Misra S. 2017. *Commercial Ornamental Crops: Traditional and Loose Flowers*. Kruger Brentt Publisher UK Ltd.
- Randhawa GS and Mukhopadhyay A. 1986. *Floriculture in India*. Allied Publ.
- Reddy S, Janakiram T, Balaji T, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi India.
- Singh AK. 2006. *Flower Crops: Cultivation and Management*. New India Publ. Agency, New Delhi, India.
- Singh AK. 2014. *Breeding and Biotechnology of Flowers, Vol.1: Commercial Flowers*. New India Publ. Agency, New Delhi, India. pp.740.

Course Code : **FLS 609**

Course Title : **Advances in Protected Cultivation of Flower Crops**

Credit Hours : **(2+1)**

Why this course ?

Protected cultivation is more rewarding in production of high value cut flowers. With appropriate structures and plant environment control measures, the constraints of environment prevalent in the region can be overcome allowing almost year- round cultivation. The students need to get updated with the recent advances in protected cultivation.

Aim of the course

Appraisal on the advances in protected and precision farming of flower crops.

The course is organized as follows:

No	Blocks	Units
1	Production technology	I Scope and Scenario II Microclimate management III Cultural operations IV Advances in flower crops

2	Precision floriculture and regulations	I Precision floriculture II Regulations

Theory

Block 1: Production technology

Unit I: Scope and Scenario: Prospects of protected floriculture in India, growing structures, basic considerations in establishment and operation of green houses, functioning and maintenance. Global trade, forward and backward linkages for import clusters, International and national auction houses.

UNIT II: Microclimate management: Environmental control systems in greenhouse, regulation of light through LEDs containers, substrate culture, soil decontamination techniques, aeroponics, hydroponics and vertical farming.

Unit III: Cultural operations: Water and nutrient management, crop regulation, special horticultural practices under protected cultivation of rose, chrysanthemum, carnation, orchids, anthurium, gerbera, lilium, cut foliage and potted ornamental crops; plant architecture managementin ornamental plants.

Unit IV: Advances in flower crops: Advances in protected cultivation of important flowering (rose, chrysanthemum, carnation, gerbera, orchids, anthurium, lilium, and foliage plants (agloenema, monstera, dracaena, syngonium, pothos, diffenbachia, etc.)

Block 2: Precision floriculture and regulations

Unit I: Precision floriculture: Precision floriculture, Principles and concepts, enabling technologies of precision floriculture, remote sensing, sensors, automation in greenhouses, solar greenhouses, retractable greenhouses. Computers and robotics, decision support systems, apps, cold chain management, use of AI for production and trade.

Unit II: Regulations: PBR/ IPR issues; Forward and backward linkages, 100% EOU, packaging and export standards, Cool chain Management, non-tariff barriers, APEDA regulations forauction houses, major markets.

Practical

- Growing structures, basic considerations in establishment and operation of greenhouses;
- Environmental control systems in greenhouse;
- Containers, substrate culture, soil decontamination techniques;
- Crop regulation;
- Special horticultural practices under protected cultivation;
- Precision equipments, computers and robotics in precision farming;
- Harvest indices – harvesting, Post harvest handling, marketing;

- Export and cold chain management.

Teaching Methods/ Activities

- Lectures
- Group discussions
- Flip classes
- Assignment and group seminars
- Hands on training of different techniques
- Exposure visits

Learning outcome

After successful completion of this course,

- The students will be abreast with the recent advances in protected cultivation offlower crops
- Equip the students with skill to independently manage enterprises

Suggested Reading

- Bhattacharjee SK. 2018. *Advances in Ornamental Horticulture*. Vols. I-VI. Pointer Publ. Reprint, 2065 p.
- Bose TK, Maiti RG, Dhua RS and Das P. 1999. *Floriculture and Landscaping*. Naya Prokash, Kolkata, India.
- Reddy S, Janakiram T, Balaji, Kulkarni S and Misra RL. 2007. *Hi- Tech Floriculture*. Indian Society of Ornamental Horticulture, New Delhi, India